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PROCEEDINGS

of the

Indiana Academy of Science

Founded December 29, 1885

VOLUME 48

PAUL WEATHERWAX, EDITOR

Field Meeting held at
McCormick's Creek State Park
May 13 and 14, 1938

Fifty-fourth Annual Meeting
Purdue University
November 3, 4, and 5, 1938

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1939

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Membership Lists—The complete list of members of the Academy was last published in Vol. 46 (1937) of the Proceedings, and supplementary lists appear in following volumes. For the effect that it may have in stimulating activity, a complete list of Junior Academies is published each year as a part of the report on the Junior Academy.

Constitution and By-Laws—The constitution and by-laws of the Academy were last published in Vol. 44 (1935). A codified list of duties of officers and chairmen of committees is published in this volume (pp. xx-xxiv).

Editorial Code—A general editorial code was published in Vol. 44 (1935). Additional directions for the preparation of manuscripts have been printed in leaflet form, and copies of this may be secured from the Editor.

Membership lists and copies of the constitution and by-laws may be secured from the Secretary.

OFFICERS AND ELECTED COMMITTEES FOR 1938

OFFICERS

President, **Eli Lilly**, Eli Lilly and Company.

Vice-President, **T. G. Yuncker**, DePauw University.

Secretary, **William P. Allyn**, Indiana State Teachers College.

Treasurer, **W. P. Morgan**, Indiana Central College.

Editor, **Paul Weatherwax**, Indiana University.

Press Secretary, **Will E. Edington**, DePauw University.

Trustees Academy Foundation, **John S. Wright**, Eli Lilly and Company, **F. B. Wade**, Shortridge High School.

Committee for Bonding Trustees, **H. L. Bruner**, Butler University, **W. A. Cogshall**, Indiana University.

Research Committee, **A. L. Foley**, Chairman, Indiana University (Term expires 1941), **E. G. Mahin**, University of Notre Dame (Term expires 1942), **H. E. Enders**, Purdue University (Term expires 1940), **Ray C. Friesner**, Butler University (Term expires 1939), **John S. Wright**, Indianapolis (Term expires 1938), **Eli Lilly**, Indianapolis (ex officio), **William P. Allyn**, Indiana State Teachers College (ex officio).

DIVISIONAL CHAIRMEN

Archeology, **Glenn A. Black**, 815 Oakland Ave., Indianapolis.

Bacteriology, **P. A. Tetrault**, Purdue University.

Botany, **Floyd E. Beghtel**, Evansville College.

Chemistry, **Frank V. Graham**, Ball State College.

Geology and Geography, **Stephen S. Visher**, Indiana University.

Mathematics, **J. E. Dotterer**, Manchester College.

Physics, **Seth Elliott**, Butler University.

Psychology, **A. R. Eikenberry**, Manchester College.

Zoology, **H. G. Nester**, Butler University.

EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

Allen, W. P.; Andrews, F. M.; Arthur, J. C.; Beghtel, F. E.; Behrens, C. A.; Black, G. A.; Blanchard, W. M.; Blatchley, W. S.; Bruner, H. L.; Burrage, S.; Cogshall, W. A.; Coulter, Stanley; Cumings, E. R.; Davis, J. J.; Deam, C. C.; Dotterer, J. E.; Edington, W. E.; Eikenberry, A. R.; Elliott, Seth; Enders, H. E.; Foley, A. L.; Friesner, R. C.; Gingery, W. G.; Girton, R. E.; Graham, F. V.; Guernsey, E. Y.; Hessler, R.; Lilly, Eli; Lyon, M. W., Jr.; Mahin, E. G.; Martin, E. S.; Montgomery, B. E.; Morgan, W. P.; Moenkhaus, W. J.; Mottier, D. M.; Nester, H. G.; Noyes, W. A.; Payne, F.; Ramsey, R. R.; Rettger, L. J.; Tetrault, P. A.; Visher, S. S.; Wade, F. B.; Wallace, F. N.; Weatherwax, Paul; Wright, J. S.; Yuncker, T. G.

STANDING COMMITTEES

(Appointed by the President, chairman of each committee named first.)

Archeological Survey: E. Y. Guernsey, Eli Lilly, W. N. Logan, Glenn A. Black, C. A. Malott, R. E. Esarey, C. F. Voegelin.

Auditing: E. S. Martin, William Johnson.

Biological Survey: B. E. Montgomery, Winona Welch, C. M. Palmer, S. R. Esten, M. W. Lyon, B. H. Smith.

Library: Walter G. Gingery, Ray C. Friesner, Nellie M. Coats.

Membership: R. E. Girton, S. W. Witmer, Floyd E. Beghtel, M. S. Markle, L. J. Rettger, Glenn W. Giddings, G. D. Klopp, O. B. Christy, W. D. Thornbury, R. E. Martin, Francis J. Wenninger, A. R. Bechtel, C. A. Deppe, Howard H. Helman, F. R. Elliott, William J. Tinkle, Henry G. Nester, Leslie I. Steinbach, D. L. Harmon, H. M. Powell.

Program: J. J. Davis, R. B. Abbott, R. H. George, H. H. Remmers, C. A. Malott, Glenn A. Black, Ray C. Friesner, C. K. Robbins, Theodore Just, R. E. Martin.

Publications of Proceedings: Paul Weatherwax, J. J. Davis, C. A. Behrens, F. B. Wade, M. E. Hufford, E. S. Conklin.

Relation of Academy to State: F. N. Wallace, J. S. Wright, Stanley Coulter, E. Y. Guernsey, Harry J. Reed, D. A. Rothrock.

Representative on A.A.A.S. Council: Howard E. Enders.

Nominations: Will E. Edington, J. J. Davis, Ray C. Friesner.

Junior Academy of Science: Howard E. Enders, F. B. Wade, O. B. Christy, W. P. Allyn, Fred J. Breeze, C. F. Cox.

MINUTES OF COUNCIL MEETING

INDIANAPOLIS, MARCH 5, 1938

The Executive Council meeting at the Indianapolis Athletic Club, held primarily to consider problems pertinent to the spring meeting and other current business needing attention before the regular meeting, was called to order by President Lilly at 1:30, following a luncheon. Twenty-five members of the committee were present: W. P. Allyn, F. E. Beghtel, C. A. Behrens, G. A. Black, W. M. Blanchard, H. L. Bruner, W. A. Cogshall, Stanley Coulter, J. J. Davis, J. E. Dotterer, W. E. Edington, A. R. Eikenberry, Seth Elliott, W. G. Gingery, R. E. Girton, F. V. Graham, Eli Lilly, E. S. Martin, W. P. Morgan, D. M. Mottier, H. G. Nester, P. A. Tetrault, S. S. Visher, Paul Weatherwax, T. G. Yuncker.

The minutes of the previous business meeting, at Manchester College, November 4, 1937, were read and approved with two minor corrections. The reference made to the Treasurer's report was corrected to read that the Treasurer submitted a brief report, and the name of W. P. Allyn was added to the list of fellows elected.

Officers and committees reported as follows:

Auditing Committee. E. S. Martin stated that the Treasurer's books at the last audit were in excellent condition. No audit has been made for the current year, since the fiscal year ends December 31.

Treasurer's Report. W. P. Morgan briefly indicated the financial status of the Academy to date with a balance of $810.01.

A discussion followed as to the advisability of transferring some of the balance to the research fund, but action was postponed until the regular fall meeting.

Editor. Dr. Weatherwax spoke briefly on the status of the Proceedings for 1938, stating that it was ready to go to press, also that an attempt was being made to publish abstracts of all papers not published in full. He asked the Council to appropriate $300 to supplement the $1,000 contributed by the state for publishing and binding the Proceedings.

The appropriation was approved.

A bill for $1,000 due the publishers of the 1937 Proceedings was brought up for discussion. Due to a minor discrepancy, the lack of the official o. k. of the Editor, this bill had not been paid. It was voted that the matter be placed entirely in the hands of Mr. F. N. Wallace, Chairman of the Committee on the Relations of the Academy to the State, for the exceution of necessary proceedings for payment of the bill.

Program Committee. J. J. Davis reported that the Committee had decided on McCormick's Creek State Park as the place for the spring meeting and that two tentative dates from which to choose were suggested, May 13 to 14 and May 20 to 21. It was voted that McCormick's Creek State Park be selected as the place and that May 13 and 14 be approved as the date.

New Business. Acting upon the previous suggestion of Professor Kintner, President Lilly appointed a committee of three, Dr. Edington, Dr. Friesner, and J. S. Wright, as an advisory committee on duties of Academy officers and committee chairmen. The function of this committee is to formulate suggestions and helps for the committee chairmen, divisional chairmen, and other officers in the performance and integration of the duties of their respective offices.

President Lilly expressed his appreciation for the attendance of the members of the Council, especially during such inclement weather, and begged that they be his guests at the luncheon. A vote of hearty appreciation of his hospitality followed, and the meeting was adjourned.

MINUTES OF THE SPRING MEETING

McCORMICK'S CREEK STATE PARK

MAY 13 AND 14, 1938

The members of the Academy assembled in the Lounge Room of Canyon Inn at McCormick's Creek State Park for the annual spring meeting. The meeting was called to order by President Eli Lilly, who welcomed those in attendance and thanked the members of the Program Committee and other officers concerned for their splendid cooperation in preparing for the meeting.

An informal program followed. Dr. Clyde A. Malott shared with the Academy his store of knowledge on "The Setting and Geological Features of McCormick's Creek Park Area." Dr. A. C. Kinsey's discussion on the "Pleistocene Glaciation Effects on Indiana Fauna and Flora" challenged certain scientific concepts concerning species variation in this area. Dr. Paul Weatherwax discussed "Plants Rare and Common in McCormick's Creek Park Area." Dr. Marcus Ward Lyon, Jr., submitted a tribute to the memory of the splendid work of the late Dr. Bebb.

President Lilly appointed the following Nominating Committee for 1938: Will Edington (chairman), J. J. Davis, and Ray C. Friesner.

The evening meeting was then adjourned.

Several trips were planned for Saturday morning, May 14, but rain interfered with the greater part of the program.

(Signed) WILLIAM P. ALLYN, *Secretary.*

PROGRAM OF THE WINTER MEETING

PURDUE UNIVERSITY
NOVEMBER 3-5, 1938

THURSDAY, NOVEMBER 3

7:00-9:00 p. m. Registration.
7:30 p. m. Meeting of the Executive Committee.

FRIDAY, NOVEMBER 4

8:00-12:00 a. m. Registration.
9:30 a. m. General Session.
Address of Welcome—Professor F. C. Hockema, Assistant to the President of Purdue University.
Response—President Eli Lilly.
Business Session.
Necrology—Dean Stanley Coulter.
Sister Amata
Charles Brossman
William Bebb
Kate G. Bitting
Fred Donaghy
Joseph P. Naylor
"The life and work of Joseph Charles Arthur."—Frank D. Kern, Pennsylvania State College.
"A tribute to Dean Stanley Coulter."—Ray C. Friesner, Butler University.
"Indiana Mastodons."—Marcus W. Lyon, Jr., South Bend.
"Marihuana."—B. H. Smith, Indiana State Teachers College.
"The distribution of corn, oats, and wheat in Indiana."—S. S. Visher, Indiana University.

1:00 p. m. Sectional meetings. See: archeology, p. 12; bacteriology, p. 33; botany, p. 44; chemistry, p. 74; geology and geography, p. 113; mathematics, p. 157; physics, p. 171; psychology, p. 183; zoology, p. 200.

6:00 p. m. Annual Dinner.
Business Session.

8:00 p. m. "Bubbles Concerto—A film fantasy."—Eiffel G. Plasterer and party, Huntington.
President's Address—"A plan for accomplishing more effective research."—Eli Lilly, Indianapolis.

SATURDAY, NOVEMBER 5

9:00 a. m. Meeting of entomologists—Chairman, Philip Luginbill, U. S. Department of Agriculture. See p. xxviii.
Meeting of plant taxonomists—Chairman, Ralph M. Kriebel, Soil Conservation Service. See p. xxviii.
Junior Academy of Science. See p. xxv.

1:00 p. m. Junior Academy of Science.

MINUTES OF THE EXECUTIVE COMMITTEE

November 3, 1938

The meeting was called to order at 7:30 by President Lilly. The minutes of the Executive Council at Indianapolis, March 5, 1938, and also those of the spring meeting, held at McCormick's Creek State Park, were read by the Secretary and approved.

Officers and committees gave the following reports:

Academy Foundation. John S. Wright, in the absence of Chairman Frank B. Wade, gave the following report as of November 1, 1938:

Receipts

Balance from previous year	$ 352.01
Total receipts	760.57
Total	$1,112.58

Expenditures

No expenditures	000.00
Balance in Indiana National Bank	$1,112.58

Present Assets at Par Value

United States Treasury Bonds	$4,700.00
Consolidated Federal Farm Loan Bonds	1,500.00
Muncie Masonic Temple Association Preferred Stock	200.00
Standard Oil Co. of Indiana Common Stock	150.00
Total invested assets at par	$6,550.00
Balance in bank (awaiting investment)	1,112.58
Grand total assets	$7,662.58

Archeological Survey. Mr. Guernsey gave an informal report of the activities of the committee for 1938, this being a continuation of work of the previous year with emphasis on studies in southern areas of Indiana.

Auditing Committee. Mr. Martin stated that, since the Academy year closed December 31, no audit was yet available for 1938. The Auditing Committee, however, had examined the books of the Treasurer and found that his report appearing in Volume 47 of the Proceedings was a true statement of receipts, expenditures, and balance on hand for the Academy.

Also the books of the Trustees of the Academy Foundation Fund were found to be correct and to agree with the report given by the trustees in Volume 47 of the Proceedings.

Biological Survey. B. E. Montgomery submitted the following report:

> The committee is pleased to be able to report that Deam's Flora of Indiana has been completed and is in the hands of the printer. Other items of interest, including the bibliography of Indiana biota, are little changed from last year.
>
> The committee wishes again to call attention of the Academy to the urgent need for a research museum within the state. It is hoped that the special committee authorized last year on the recommendation of our committee will be able to report progress on the preliminary steps for such museum.

Bonding Committee. Dr. H. L. Bruner, who was unable to be present, submitted a written report to the effect that the premium of $15.00 on the bond for the Treasurer and Trustees of the Academy was due.

Payment of the bill was authorized.

Editor. Dr. Weatherwax, Editor, reported that Volume 47 was delivered to the State Library in August. The details pertaining to the publication of the volume are as follows:

Number of copies printed	1600
Number of pages printed	324
Cost of printing and binding	$1,432.22
Cost of reprints furnished gratis to authors	58.53
Cost of reprints of necrology and membership list	17.70
Editorial assistant	180.20
Editor's expenses for postage, envelopes, etc	10.00
Total cost of publication	1,698.65
Amount paid by the Academy	698.65
Total cost per printed page	5.24
Net cost per page of manufacture	4.41

The net cost per printed page has increased about 10% in the past two years. A part of this is attributed to the new scale of contract prices and a part to the condensation of material on the pages. Random samples indicate that the cost per unit of printed matter has shown no material increase.

Dr. Weatherwax also stated that, so far as possible, abstracts of all papers were published.

It was also asked by Dr. Weatherwax that a stipulated sum to be used in publishing the Proceedings be named by the executive committee. The Treasurer suggested that the financial standing of the Academy would permit an expenditure equal to that of last year for publishing the Proceedings.

An amended motion, to the effect that the amount to be spent on the publication of the Proceedings for 1938 be left to the discretion of the Editor and the Treasurer, provided that it did not exceed $600, was passed.

The expenditure of an amount not to exceed $200 for editorial assistance was authorized.

Library Committee. W. G. Gingery read the following report prepared by Miss Nellie Coats of the State Library:

Since the last annual report 25 new titles, a list of which is appended, have been added to the number of serials received by the Library, making a total of about 300, representing material from 39 states, the Philippines and Hawaii, and 37 foreign countries. An effort is made not only to acquire material representing various scientific fields but to extend the geographic range as widely as possible. We hope to acquire material from such states as are not represented, if material is available, and to expand the foreign mailing list. The foreign countries now represented are: Argentina, Australia, Austria, Belgium, Borneo, Brazil, Canada, Chile, China, Czechoslovakia, Denmark, Dutch East Indies, England, Finland, France, Germany, Greece, Hungary, India, Ireland (Northern), Italy, Japan, Latvia, Mexico, The Netherlands, Norway, Peru, Poland, Portugal, Roumania, Russia, Scotland, South Africa, Sweden, Switzerland, Ukrania, and Uruguay.

Recently the new edition of the National Research Council Handbook of Scientific and Technical Societies and Institutions of the United States and Canada and the 1937 Index Generalis were checked for names and addresses of additional scientific societies and institutions with which it might be profitable to establish the exchange of publications, and letters have been sent to 52 societies and universities asking that such an arrangement be made.

In May, 1938, a letter was received from the National Library of Peiping, China, which we quote:

"Owing to Japan's military occupation of Peiping, we have established an office in Hongkong. We have been collecting books and journals in order to meet the intellectual needs of Chinese scholars in this hour of distress. As many of our universities and scientific institutions have been deliberately destroyed by Japanese militarists, the need of scientific literature felt by Chinese scholars is most urgent.

"Cognizant of your intellectual sympathy for China, we earnestly hope that you will find it possible to send us a set of the following publications issued by your Academy: Transactions, other publications which you distribute to cultural institutions.

"If you would kindly comply with our request, your courtesy will be gratefully appreciated.

"As we have to start our work entirely afresh, we shall greatly appreciate your assistance if you could send us also your duplicate material which you no longer wish to keep.

"Donations of books from your Academy will temporarily be kept in Hongkong and will be properly catalogued and made immediately available for use. As scientific work is being carried on in China despite of the war, your publications will render a great service to the present and future generations of scientific workers in this country.

"In order to save you the trouble of posting your publications to China, we may suggest that you forward them to the International Exchange Service, Smithsonian Institution, Washington, D. C., which would arrange their shipment to us at our Hongkong address. The current issues of your serial publications, however, should be sent by mail so that Chinese scholars will be able to keep in touch with your scientific work.

"Thanking you in anticipation for your cooperation and assistance, I remain

"Very truly yours,

"(Signed) T. L. YUAN, *Acting Director.*"

The following year books were sent in response to this request: 1887, 1889, 91, 93-1913, 1915, 1919, 1924, 1927, 1930, 1931, 1935-37,

The work of checking titles for entry in the Union list of serials in Indiana libraries, sponsored by the College Reference Librarians of Indiana, is nearing completion, and the list should be ready for publication within the year. It is thought that inclusion in this list will greatly add to the library's usefulness.

With the Academy's appropriation of a sum for binding for the years 1937-38 and 1938-39 it is hoped that most of the complete files will be bound during this two-year period. Late in 1937, 445 volumes of serials, chiefly publications of foreign scientific organizations, were bound, and it is estimated that about as many volumes are now ready for binding. These will be prepared and sent to the bindery in the very near future. There will remain the task of filling in incomplete files and binding material received each year. Every effort has been made to secure missing numbers by gift or exchange from the issuing societies or institutions, and it is fairly evident that volumes now remaining incomplete can only be completed by the purchase of the missing numbers if that is considered advisable.

Titles Added to the Library Since 1937

Association canadienne francaise pour l'advancement des sciences anales. 1, 1935.
Archives néerlandaises de phonetique experimentale v. 4, 1929.
Athens. University. Zoological institute and museum Acta v. 1, 1935.
Australian zoologist v. 1, 1914.
La bonne terre. Ecole superieure d'agriculture v. 19, December, 1937.
Chicago naturalist. Chicago academy of science v. 1, 1938.
Condor v. 40, 1938.
Fysiografiske sallskapets. Lund, Sweden. Forhandlingar v. 6, 1936.
Harvard university. Museum of comparative zoology Bulletin v. 78, 1935.
Hawaii. University Research publications no. 8, 1933.
Instituto pan-americano de geografia e antropologia a americano Boletin bibliografico de antropologia americano v. 1, 1937.
London. Science museum. Science Library. Weekly bibliography May, 1937.
Missouri academy of science Proceedings 1934-35.
New Orleans academy of science Abstracts of papers 1938.
Northwest science. Northwest scientific association v. 1, 1927.
Rivista de biologia coloniale. Rome v. 1, 1938.

Royal Ontario museum of zoology Contributions 1, 1935.
Royal zoological society of New South Wales Proceedings 1935-36.
Saratov. Universität Abhandlungen: Chemische serie 1, 1936.
Saratov. Universität Geoglogisch-bodenwissenschaftlichen serie 1, 1937.
Scripps institution of oceanography Contributions n. s. 1, 1937.
Shanghai science institute Journal 1933.
Societas pro fauna et flora Acta v. 58, 1935-36.
Societe entomologique de Belgique Bulletin et annales v. 75, 1935.
Yale university. School of forestry Bulletin no. 43, 1936.

Membership Committee. R. E. Girton, Chairman, stated that 55 applications for membership in the Academy were obtained for the fall meeting. To this list should be added seven other names of those elected at the spring meeting.

It was suggested that all members of the Academy should be on the alert for prospective new members in order that the membership may show a positive growth during the years to come.

Press Secretary. Dr. Edington gave the following summary of the activities of his office:

Reports of the Spring Meeting of the Academy were sent to the Indianapolis papers and to the Editor of *Science*. Reports of the present meeting have appeared in the Indianapolis papers and in papers elsewhere. The Indianapolis News carried an editorial in its issue of November 2, commenting favorably on the work of the Academy and the scientists of the State. Since clipping service is not available, the Press Secretary has no means of ascertaining how extensive over the State the Academy publicity may be Abstracts of most of the papers to be presented before the Academy have been received, and it is planned that stories on some of them will be released on the day of the presentation of the papers.

Relations of the Academy to the State. Frank N. Wallace stated that his committee had made a request for $1,500 from the state, the same amount as that granted last year, for the publication and binding of the Proceedings—$1,000 for publication of Proceedings and $500 for binding Proceedings and other manuscripts and records belonging to the Academy.

Research Committee. Dr. Foley gave a brief report of grants made for 1938 but stated that no application for future grants had been received by the committee.

The committee awarded $75 to S. S. Visher, Indiana University, for clerical help in the analysis of climatological data and for traveling expenses to meteorological stations of the state.

A grant of $125 was awarded to Dr. W. M. Blanchard, DePauw University, to continue studies of new methods for synthesizing derivatives of mandelic acid, investigations on the composition of certain vegetable oils, and preparation of ozetidine derivatives.

It was proposed by the committee when the grants were made that $150 of the total sum be furnished by the research grant from the A.A.A.S. to the Academy, and the remaining $50 be paid from the funds of the Academy. It was reported that $150 had been received from the A.A.A.S. and that both grants, as indicated, had been paid in full to the grantees.

The Chairman stated that reports on the progress of the research work had been received from Dr. Visher, but that, on account of illness, no report had been received from Dr. Blanchard.

Treasurer. Dr. W. P. Morgan submitted a tentative report to cover the period from January 1 to October 31, 1938. The following report for the fiscal year, ending December 31, 1938, was later submitted:

Receipts

Balance on hand January 1, 1938	$810.01	
Dues and Initiation fees	856.00	
A. A. A. S. refund for research grants	150.00	
Sale of Proceedings	21.32	
Sale of separate numbers of journals	4.25	
Return of unused research grant (Martin)	1.40	
Authors' reprints, Volume 46	4.89	
Authors' reprints, Volume 47	293.57	
Bequest from estate of Dr. Stoltz	40.00	
		$2,181.44

Disbursements

Program Committee	$126.00	
Expenses of Editor	207.50	
Expenses of Secretary	80.78	
Expenses of Treasurer	47.00	
Mailing Proceedings	95.52	
Stationery	55.35	
Indianapolis Engraving Co.	183.25	
Wm. B. Burford Printing Co.	783.63	
Junior Academy, Science club bulletins	20.00	
Surety bond and safety deposit box	20.50	
Expenses local committee, A. A. A. S. meeting	31.81	
Payment of Stoltz bequest to Foundation	40.00	
Research grants (Wilson, $75; Blanchard, $125; Visher, $75.00)	275.00	
Returned check	4.02	
Bank service charge	.50	
Expense refund to officers and chairmen	12.15	
		$1,983.01
Bank balance		198.43
		$2,181.44

The balance indicated above as carried forward from 1937 is $1.00 more than that published in the preceding annual report, due to a loss of a check for $1.00 by an officer. This is covered by a duplicate listed under the last in the above list of disbursements.

(Signed) W. P. Morgan, *Treasurer.*
Ersie S. Martin, *Auditor.*
Wm. Johnson, *Auditor.*

Junior Academy Committee. Dr. Enders reported that to date there are about forty active junior organizations and several prospective clubs under consideration. A mailing list and visitation itinerary have been established in order to familiarize the high schools of the state and capture their interest with this phase of the Academy's program.

It was emphasized that exhibits of the Junior Academies would be on display Saturday morning and that it would be not only interesting to visiting members of the Academy but also stimulating to the Junior Academy representatives if they were honored by the attendance of members of the senior Academy.

At the suggestion of Dr. Enders, it was voted to appropriate $20 again this year for the cooperative publication, with the Illinois Academy, of the Science Club Service to be distributed among the Junior Academies and prospective clubs.

Nominating Committee. Dr. Joseph Charles Arthur was nominated as Honorary Fellow, and the following were nominated as Fellows: F. E. Beghtel, Ralph Kriebel, W. D. Thornbury, F. V. Graham, and B. H. Smith. H. L. Bruner and W. A. Cogshall were nominated to succeed themselves on the Bonding Committee, and John S. Wright to succeed himself on the Research Committee, his term to expire in 1943.

All the above nominees were elected. The nominations of other officers of the Academy were withheld until the dinner meeting.

Necrology. Dean Coulter, who has for many years collected data for the necrology, requested that this duty be assigned to a younger man with close acquaintance with the membership and affairs of the Academy. It was voted that this duty be assigned to Dr. Will E. Edington until a change was officially designated.

Relation of High School Teachers to the Academy. Means of encouraging high school teachers to attend the Academy were discussed. Dr. Edington stated that the permission for teachers to be absent from duty in order to attend the Academy meetings lay entirely in the hands of local school officials and that, through local science clubs, school officials might be encouraged to recognize the value of these meetings and to cooperate.

It was voted that a committee be appointed to acquaint school officials with the program of the Academy and to enlist their cooperation in the participation of teachers in Academy programs.

Program Improvement. It was decided in 1937, at the suggestion of a special committee under Dr. Friesner, that papers of special merit read before the Academy be selected by the Research Committee and given honorable mention at the dinner meeting following the sectional meetings.

Dr. Foley, Chairman of the Research Committee, asked that this be omitted this year and indefinitely until satisfactory machinery could be organized for handling this problem. He stated that the magnitude of the job and brevity of time during the course of meetings presented a physical impossibility. Dr. Foley's request was granted. It was suggested that honorable mention of worthy papers might be made at the first succeeding annual meeting.

Correlation of Duties of Officers. Dr. Edington, as Chairman, reported that the special committee on duties of officers, which had been authorized by the Council at its meeting in March, had practically completed its work. He gave a brief resume of what had been accomplished and asked that the completed report be mimeographed for immediate use and also published in the Proceedings and that reprints be prepared for distribution to officers in the future. The report was approved, and its publication was authorized. (The codified list of duties of officers is published in full on pages xx to xxiv.)

President Lilly appointed the following committees: *Invitations*—L. A. Test, Glenn A. Black, and O. B. Christy; *Resolutions*—C. A. Malott, Paul Weatherwax, and B. E. Montgomery.

The meeting adjourned at 10:30 p. m.

MINUTES OF THE GENERAL SESSION

The meeting, with 433 registrations, was called to order at 9:30 a. m. in Eliza Fowler Hall by President Lilly. An address of welcome was given by Professor F. C. Hockema, Assistant to the President of

Purdue University. President Lilly responded briefly to the welcome and expressed the appreciation of the Academy for the hospitality extended by the University.

In the brief business session which followed, the action of the Executive Committee was approved. J. J. Davis, Chairman of the Program Committee, commented briefly on minor changes which had been made since the printing of the program.

Dean Coulter paid appropriate tribute to the memory of six members of the Academy whose deaths had occurred during the past year: Sister Amata, Kate G. Bitting, Charles Brossman, William Bebb, Fred Donaghy, and Joseph P. Naylor.

The meeting adjourned at 11 o'clock, a. m., and the sectional meetings convened at one o'clock.

The annual Academy dinner was held in the Purdue Union Building at 6 p. m. A short business meeting followed the dinner. Dr. Girton, Chairman of the Membership Committee, submitted the names of 54 applicants for membership, and all were elected.

The Resolutions Committee offered the following resolution:

> The Indiana Academy of Science, assembled at Purdue University in its fifty-fourth annual meeting, expresses its sincere appreciation for the hospitality offered by the University, for the careful preparations made by its Program Committee under the leadership of Professor J. J. Davis, for the efficiency and interest demonstrated by its officers, and for the presence of a large number of its membership, who demonstrate their interest in the progress of science in Indiana by their presence and participation in the programs.

The Committee on Invitations recommended that the Academy accept the invitation of the Indiana State Teachers College to be the host for the Academy at its next annual winter meeting, 1939. The recommendation was approved.

The Nominating Committee announced the election of the Division Chairmen as follows: *Archeology,* Paul Weer, Indianapolis; *Bacteriology,* W. A. Jamieson, Eli Lilly and Company; *Botany,* Winona Welch, DePauw University; *Chemistry,* Herman T. Briscoe, Indiana University; *Geology and Geography,* Thomas M. Bushnell, Purdue University; *Mathematics,* P. D. Edwards, Ball State Teachers College; *Physics,* R. B. Abbott, Purdue University; *Psychology,* F. B. Knight, Purdue University; *Zoology,* C. P. Hickman, DePauw University.

The following were nominated for officers for 1939: *President,* T. G. Yuncker, DePauw University; *Vice-President,* L. A. Test, Purdue University; *Secretary,* W. P. Allyn, Indiana State Teachers College; *Treasurer,* W. P. Morgan, Indiana Central College; *Editor,* Paul Weatherwax, Indiana University; *Press Secretary,* W. E. Edington, DePauw University. It was voted that the Secretary be instructed to cast a unanimous vote for the election of these nominees.

The meeting was then placed in charge of the new President, and Retiring President Lilly delivered a very interesting and thought-provoking address on "A Plan for Accomplishing More Effective Research."

Entertainment followed and the meeting was adjourned.

(Signed) W. P. ALLYN, *Secretary.*

DUTIES OF OFFICERS

The following list of duties of officers and committee chairmen of the Academy was prepared by a special committee, consisting of Will E. Edington (Chairman), John S. Wright, and Ray C. Friesner, and approved by the Executive Committee at the Winter Meeting of 1938.

President

1. To preside at all meetings of the Academy except when relieved by the Vice-President.

2. To appoint the members of the standing committees and any special committees. To appoint the members of the Nominating Committee, Invitations Committee, and Resolutions Committee. It is suggested that the Nominating Committee be chosen from past presidents.

3. To approve the current bills of the Academy.

4. To deliver an address, known as the Presidential Address, at a time specified by the Program Committee.

5. To cooperate closely with the Committee on Relation of the Academy to State in the securing of funds for the publication of the Proceedings, library improvements, and similar projects.

6. To call special meetings of the Council or Executive Committee as occasion demands. A special Council Meeting is generally held in late February or early March in order to make general plans for the year.

7. To perform other such duties as pertain to the office.

Vice-President

1. To preside in the absence of the President and otherwise at the request of the President.

2. To preside and introduce the President at that session or that part of the session at which the President makes his Presidential Address.

3. To perform other such duties as usually pertain to the office.

Secretary

1. To keep the minutes of the meetings of the Council, the Executive Committee, and of all General Sessions of the Academy, and to prepare these minutes for publication in the Proceedings. The form in which these minutes should appear may be found in past volumes of the Proceedings. The minutes of the Executive Committee just preceding the General Winter Meeting should be prepared for reading at the General Meeting the following morning. Also the nominations for fellows of the Academy should be presented at this General Meeting.

2. To furnish the President or other officers complete copies of the minutes or such parts as they may specifically request.

3. To notify promptly the President and Committee Chairmen of any items in the minutes which they should know or which require their action.

4. To keep a complete file of the membership of the Academy as furnished by the Treasurer, and to have charge of the mailing lists of all Academy notices and the Proceedings, and to supply such lists upon request to the Chairman of the Program Committee and the proper officials of the State Library.

5. To notify the Chairman of the Program Committee that, upon his request, addressed envelopes will be supplied him for mailing:

    a. Preliminary Spring Meeting notices, these to be window envelopes and to include addressed dues notices, the amounts to be filled in by the Treasurer.
    b. Final Spring Meeting notices.
    c Preliminary Winter Meeting notices.
    d. Final winter program.

6. To address dues notices for Treasurer upon his request. When a new treasurer is elected, to inform him of this service.

7. To address envelopes for Chairman of the Program Committee. Three sets are needed: one for final Spring Meeting announcement, one for preliminary Winter Meeting announcemet, and one for final Winter Meeting announcement. Preliminary Spring Meeting announcements go out in window envelopes containing also the dues notices. Final notices of meetings are sent to non-resident members.

8. To address labels for mailing out Proceedings to active members. Check slips against "dues paid" for years for which Proceedings are current. Those who have not paid dues receive no Proceedings. Non-resident members who pay no dues do not receive the Proceedings.

9. To prepare membership roll after the Winter Meeting. Make at least two copies and send one copy to the Editor and keep one copy in reserve.

10. To keep on file statements as to the duties and modes of procedure of the Chairman of the Program Committee, the Chairman of the Research Committee, and the chairmen of the divisions, and to inform these various chairmen of their respective duties in sufficient time preceding the meetings See duties of these officers.

11. To secure Academy stationery. For amounts and those to whom it goes see yearly card records filed with minute book.

12. To notify all new members of their election. Use form cards.

13. To send notices to all members elected as Fellows or Honorary Fellows or otherwise honored. Send notices to all newly elected officers who were not present when election was held.

14. To send copies of all resolutions to persons concerned.

15. To send the new President a list of all old committees with suggestions regarding new committees.

16. To send out lists of committees to all members of committees as soon as they are appointed by the new President. Include a note informing chairmen that reports will be expected at the Winter Meeting.

17. To notify all members of Executive Committee of all meetings of this committee. The Executive Committee consists of present officers, past presidents, chairmen of standing committees, and divisional chairmen. Notify them one month before Winter Meeting and remind them of written reports due at the Winter Meeting.

18 At the request of the President, to notify all members of the Council concerning meetings of the Council. The Council is composed of the officers of the Academy.

19. To inform the Chairman of the Nominating Committee one month preceding the Winter Meeting that the nominations of Fellows and Honorary Fellows must be presented at the Executive Committee Meeting.

20. To correct membership file whenever changes of address occur. Change must also be made on addressograph stencil. Destroy old stencil, and type card for the new one. Send cards to Elliott Addressograph Company, Indianapolis, for stencils twice annually, about January 1 and August 1. Inform Treasurer of all changes of address as they come.

21. All current bills of the Academy must be approved by the Secretary and the President before they are paid by the Treasurer. Approval of bills should be given promptly so that, whenever possible, discounts for cash may be secured.

22. Preceding meetings of the Executive Committee, to prepare for the President an order of business and bring to his attention any matters of incomplete business as found in the minutes of the preceding meeting.

23. At all meetings of the Council, Executive Committee, and general Academy, to have available the minute book containing the constitution and by-laws, list of committees and editor's code, and also a copy of the last Proceedings.

24. To perform other such duties as usually pertain to the office.

Treasurer

1. To handle all funds of the Academy currently received and not otherwise provided for.

2. To keep the financial records of the Academy, and to pay all bills of the Academy that have been previously approved by the President and the Secretary.

3. To notify the members annually of their standing as to membership dues, and to render statements to members for charges for reprints, etc. At the request of the Treasurer, the Secretary will send to the Treasurer the addressed dues notices, upon which the Treasurer will fill in the proper amounts before sending the notices to the Chairman of

the Program Committee so that the dues notices may be sent out with the preliminary Spring Meeting notices.

4. To inform the Secretary concerning the addition of new members and the dropping of old members for non-payment of dues, so that the membership lists may be kept correct and up to date. The Treasurer should turn over promptly all "dues paid" cards to the Secretary.

5. To receive all refunds from the A. A. A. S., such refunds to be used only for research grants as recommended by the Research Committee and authorized by the Academy.

6. To receive such funds from the Academy Foundation as have been allotted for research grants, and to pay such funds to research grantees as have been recommended by the Research Committee and authorized by the Academy. See Proceedings for 1938, Volume 47, page 10.

7. To prepare tentative and permanent statements showing clearly the financial status of the Academy, and to prepare and have audited a financial statement at the end of the fiscal year for publication in the Proceedings. A tentative statement should be presented at the Winter Meeting of the Executive Committee, and the Treasurer should anticipate receipts and be prepared to advise the officers in matters involving appropriations.

8. To provide the Editor with information concerning the status of members submitting papers for publication.

9. To perform other such duties as may pertain to the office.

Editor

1. To edit all manuscripts of papers presented on the programs of the Academy which are submitted and accepted for publication in the Proceedings. See statement of editorial policy and editorial code in the Proceedings, Volume 44, page 257.

2. To make such contracts and arrangements as are necessary for the publication of the Proceedings and as are consistent with the accepted policy of the Academy in its cooperation with the state in such publication.

3. To approve all bills arising from the publication of the Proceedings and to send these bills to the President and Secretary for their approval before payment by the Treasurer.

4. To file with the Treasurer statements of all charges for reprints and any other charges incurred by members in the publication of the Proceedings.

5. To publish in each volume of the Proceedings a statement referring to the report on the duties of officers and giving the number of the volume in which it is published.

Press Secretary

1. To have general charge of the publicity of the Academy and to prepare for the use of college directors of publicity, reporters, and editors such material as will inform the citizens of the state as to the nature of the activities and the purposes of the Academy.

2. To gather photographs, programs, and other material of general and historical interest for the files of the Academy in the State Historical Library.

3. To prepare statements concerning the meetings of the Academy suitable for publication in *Science*.

4. To cooperate with publicity directors of the institution where the Academy may be holding its meetings in the preparation of any publicity which the institution may deem desirable concerning the Academy and its activities. Photographs of officers and outstanding speakers should be secured whenever possible at least one month preceding the Winter Meeting and of new officers immediately following their election.

5. The photograph of each new president and any other outstanding member should be secured and placed in the Academy files in the State Historical Library.

Chairman of the Program Committee

1. In cooperation with his committee, to choose the place and prepare the program for the Spring Meeting of the Academy.

2. To prepare the general program for the Winter Meeting, and to appoint a local committee on arrangements to assist in the work of preparing for the meeting.

3. To compile the special programs as received from the divisional chairman, and to prepare and have published complete programs of all meetings of the Academy, together with such additional information as may be deemed necessary for the convenience of the members, such as hotel accommodations, road information, transportation facilities, etc.

4. To send to each member of the Academy the programs of the various meetings. The addressed envelopes are to be prepared by the Secretary and forwarded to the Chairman of the Program Committee at the Chairman's request.

5. To have general charge of all arrangements for the meetings of the Academy, such as luncheons, banquets, hotel arrangements, transportation, the providing of lanterns and screens, suitable locations for Junior Academy exhibits, etc.

6. To cooperate with the Academy Committee on the Junior Academy of Science in the making of the plans and arrangements for the meetings of the Junior Academy. The program of the Junior Academy Meeting is published as a part of the program of the Winter Meeting of the Academy.

7. To arrange, if possible, an information system whereby during the division meetings the members of the various divisions may be kept informed as to what papers are being read in the various divisions.

8. To receive the abstracts in triplicate of papers presented on the general program and promptly to send one abstract to the Editor, one to the Press Secretary, and one to the Chairman of the Research Committee.

9. To secure for announcement in the Winter Meeting program, a list of the names of all Academy members who have become deceased during the year, and to cooperate with the Academy necrologist in the preparation of memorials. Write to the Secretary for information.

10. To provide, when considered necessary, maps of the campus or neighborhood in which meetings are held.

11. In planning the menus of luncheons and dinners, to provide, as far as possible, for the special needs of those members who, because of religious or other limitations, may prefer foods other than those ordinarily served.

12. To make special arrangements, when necessary, for the care of colored members of the Academy and the Junior Academy.

13. To cooperate with the Secretary and Treasurer in the sending out of preliminary and final notices of meetings and to have all program material prepared, published, and mailed out at least one week before a meeting.

Divisional Chairman

1. To preside over the meetings of his division.

2. To appoint a divisional nominating committee who will recommend candidates for the office of divisional chairman for the following year. This does not preclude nominations from the floor.

3. To see that his successor is elected by his division for the next year's meetings of his division, and to report such successor's name to the Chairman of the Nominations Committee immediately after the close of the divisional meeting so that the election of his successor may be confirmed by the Academy in general session.

4. To receive all titles and abstracts of papers submitted for presentation at the divisional meetings and to select the papers for the program of the division. The program is then to be turned over promptly to the Chairman of the Program Committee. Abstracts should be received in triplicate, and one copy of each abstract should be sent to the Editor of the Proceedings, one copy to the Press Secretary, and the third copy to the Chairman of the Research Committee with any comments as to its value for consideration for worthy mention. These abstracts should be sent promptly to the above mentioned officers.

5. It is recommended that the divisional chairman present an address, not to exceed thirty minutes in length, before the forenoon meeting of the division over which he presides.

Chairman of the Research Committee

1. To have charge of all research projects of the Academy.

2. To receive all applications for research grants, and to report to the Academy all such recommendations as the Research Committee may make.

3. To receive from the divisional chairmen abstracts of all papers to be presented before the various divisional meetings of the Academy, and from the Chairman of the

Program Committee abstracts of papers to be presented at the General Meeting of the Academy. The Research Committee will use these abstracts as an aid in the determination of such papers as may be deemed worthy of honorable mention.

4. To appoint referees or judges in each division, who will report on the relative merits of the papers presented before the division as a final means of determining the paper or papers deemed most worthy of honorable mention for that division.

5. To report at the dinner meeting the names of the authors of the papers considered worthy of honorable mention, as determined by the Research Committee.

Chairman of the Nominations Committee

1. It is important that the officers of the Academy be members who are sincerely interested in the work of the Academy. They should possess some executive ability and they should be dignified and temperamentally fitted for the positions for which they are nominated. The Chairman of the Nominations Committee should be familiar with the names of past presidents, which may be secured from certain past Proceedings or from the Secretary. The officers to be chosen are President, Vice-President, Secretary, Treasurer, Editor of the Proceedings, Press Secretary, Trustees of the Academy Foundation, and members of Committee for Bonding Trustees. The first six officers are chosen annually. The other officers are chosen only as the terms of incumbent officers expire. The nominations of the first seven officers are made at the dinner meeting or the general session following it. The members of the Committee for Bonding Trustees are appointed by the Executive Committee, and such nominations should be made at the Winter Meeting of the Executive Committee.

2. The Chairman of the Nominations Committee should receive the nominations for Fellows and Honorary Fellows previous to the annual Winter Meeting of the Executive Committee. The Nominations Committee then submits its recommendations to the Executive Committee at the annual Winter Meeting. The maximum number of Fellows that may be elected in any one year is five. Members of the Academy who may have been elected Fellows in the American Association for the Advancement of Science automatically become Fellows of the Academy.

3. Following the close of the divisional meetings, the Chairman of the Nominations Committee will receive from the incumbent chairman of each division the name of the member of that division nominated for divisional chairman for the coming year. The nominations of these divisional chairmen are presented at the dinner meeting, along with the nominations of other officers, by the Chairman of the Nominations Committee.

4. Immediately following the election, the Chairman of the Nominations Committee should file a list of the officers nominated with the Secretary and the Press Secretary.

Chairman of the Invitations Committee

1. To receive the invitations of institutions desiring to entertain the Academy at its next annual Winter Meeting, and to report the recommendations of the Committee at the dinner meeting.

Chairman of the Resolutions Committee

1. To prepare resolutions for courtesies extended by host institutions and local committees.
2. To prepare any other resolutions required by the Academy, through special action of the Academy.
3. To present these resolutions at the dinner meeting of the Academy.
4. To file a copy of each resolution with the Secretary.

JUNIOR ACADEMY OF SCIENCE

Officers for 1938:

President: **Eloise Crosby**, North Side High School, Ft. Wayne.
Vice-President: **Donald Frier**, West Lafayette High School.
Secretary: **James Beltz**, Elmhurst High School, Ft. Wayne.

PROGRAM OF EIGHTH ANNUAL MEETING

November 5, 1938

10:00—General session. David Williams, Sciemus Club, Valparaiso, presided.

10:30—Bubbles program by Eiffel G. Plasterer and party.

11:00—Short papers by members:
"Photography," Robert Weiss, Sciemus Club, Valparaiso.
"Setting Up a Home Laboratory," Roy Harlow, Sciemus Club.
"Ecology of a High School Nature Preserve," Grace LaMar and Esther Rainey, Nature Study Club, Technical High School, Indianapolis.

11:30—Business session—Election of officers.

1:00—Principal address:
"A College Girl's Adventures as a Naturalist on the Barren Grounds of the Arctic," Mrs. Marguerite Baumgartner, East Lansing, Michigan.

2:00—Short papers by members:
"Bee Culture," Dorothy Barnhart, Science Club, Wabash.
"Incubation of American Woodcocks," Madge Norwood, Science Club, Wabash.
"How to Make an Insect Collection," Evelyn Lachowiez, Biology Club, Lew Wallace High School, Gary.
"Sexuality in Thallophytes," Howard Morris, Science Club, Bloomington.
"Commercial Beekeeping," Jules O. Hendricks, Science Club, Bloomington.
"Distillation of Wood," Ellwood May, Science Club, Mishawaka.
Other papers.
Reports on progress of the Indiana Junior Academy of Science in 1938, Dean Howard E. Enders, Purdue University.

MINUTES OF BUSINESS SESSION

The Indiana Junior Academy of Science held its eighth annual meeting in the Stanley Coulter Hall, Purdue University, November 5, 1938, with David Williams, of the Sciemus Club of Valparaiso High School, presiding.

Officers elected for 1939 were: *President,* Eloise Crosby, North Side High School, Ft. Wayne; *Vice-President,* Donald Frier, West Lafayette High School; *Secretary,* James Beltz, Elmhurst High School, Ft. Wayne.

Mr. J. H. Otto, George Washington High School, Indianapolis, was chosen as successor to G. W. Wade, Crispus Attucks High School, Indianapolis, to serve as a member of the Council from 1938 to 1943. (The other members of the council are: C. O. Pauley, 1934-1939; F. J. Breeze, 1935-1940; Anna Inskeep, 1936-1941; and Lola Lemon, 1937-1942.)

The attendance of members and sponsors totalled 265.

The meeting adjourned at 4 p. m.

David Williams, *President,*
Mary Penrod, *Secretary.*

EXHIBITS

The exhibits were installed early Saturday morning in the General Biology Laboratory, every table in the room devoted to exhibits from the several clubs. Keen interest was manifested by members of the visiting clubs as well as by those who demonstrated their own exhibits.

The following exhibits were prepared:

1. Nature Study Club, Technical H. S., Indianapolis, C. F. Cox, Sponsor: 15 pictures; 4 paintings; 15 herbarium sheets; flower calendar of Nature Preserve.
2. Nature Study Club, North Side, Ft. Wayne H. S., Vesta Thompson and H. S. Michaud, Sponsors: herbarium book; scrap book; moss terrarium; insect collection; potatoes raised as club project.
3. Science Club, Bloomington H. S., M. M. Williams, Sponsor: aeroplane with motor (demonstration).
4. Science Club, Mishawaka H. S., Darl F. Wood, Sponsor: distillation of wood, showing still, etc.; apparatus to liquefy ammonia; sodium atom; burnt wood drawings.
5. Science Club, Lowell H. S., R. J. Brannock, Sponsor: insect collection.
6. Science Club, Wabash H. S., R. D. Black, Sponsor: photomicrographs; snakes; radio actuated by electronic cell (demonstration).
7. West Lafayette High School Science Club, Anna Inskeep, Sponsor: soils; stamp collection; 3 varieties of Bryophyllum; wild flowers (Rocky Mt. Region); crystal oscillator; communications; anatomical plaster paris molds and casts; steps in polishing gems; gems; projects in enlarging photos.
8. Science Club, George Wahington H. S., Indianapolis, J. H. Otto, Sponsor: leaves; rocks; minerals.
9. Geography Council, North Side H. S., Ft. Wayne, F. J. Breeze, Sponsor: large map showing utilization of land along Hayden Rd.

10. Biology Club, Lew Wallace H. S., Gary, Lola Lemon, Sponsor: 12 leaf herbarium books; 7 insect collections.

11. Sciemus Clubs, Valparaiso H. S., C. O. Pauley, Sponsor: static machine (demonstration); aeroplane; polariscope; arc light; light detector; fluorescence under ultra-violet rays.

12. Shortridge Chemistry Club, Indianapolis, Lois Martin, Sponsor: not displayed.

JUNIOR ACADEMIES OF SCIENCE

Town	Club	Date of Affiliation	Sponsor
North Madison	*Hilltop Nature Study Club	1931	A. J. Slaton
Valparaiso	*Sciemus Club	1931	C. O. Pauley
Bloomington	*General Science Club	1931	M. M. Williams
Indianapolis Crispus Attucks	*Biology Club	1931	C. E. Ransom
Crawfordsville	*Audubon Society	1931	Emmett Stout
Indianapolis Shortridge	*Chemistry Club	1931	Lois Martin
Union City	*Science Club (inactive)	1932	
Indianapolis Technical	*Nature Study Club	1932	C. F. Cox
Coesse	*Jolly Hiking and Nature Club	1932	Chas. Luther (No report)
(Whitley County)	Wash. Center Hiking and Nature	1932	(No report)
Anderson	Science	1936	M. J. Brozier
Bloomington University School		1938	W. B. Miner
Cambridge City	Tri Science	1934	J. L. Bozarth
East Chicago Roosevelt	Edison	1935	Harry Apostle
Ft. Wayne Elmhurst	Phy-Chem	1937	Ruth Wimmer
Ft. Wayne	Geography Council	1932	F. J. Breeze
North Side	Science	1936	Vesta Thompson and H. H. Michaud
	Phy Chem	1936	H. A. Thomas
Gary Lew Wallace	Biology	1935	Lola Lemon
Gas City	Science	1936	Roy McKee
Greencastle	Science	1936	F. N. Jones
Guilford	Science	1936	
Hammond Thos. Edison	Nature Lore	1937	H. J. Bjorklund
Indianapolis Geo. Wash.	Science	1937	J. H. Otto
Lowell	Science	1935	C. N. Seeright
Madison		1938	Evans Cottman
Marion	Science	1936	Mrs. Pauline Mayhugh
Mishawaka	Science	1936	Darl F. Wood
Montmorenci	Jr. Acad. of Sci	1933	I. W. Vance
Mooresville	Science	1936	Fitzhugh Lee
Muncie Blaine Jr.	Science	1934	F. Kyger
New Albany	Jr. Acad	1935	Gladys Knott
Paoli	Science	1935	O. R. Whitlock
Tipton	Jr. Science	1933	W. D. Hiatt
Wabash	Science	1936	R. D. Black
West Lafayette	Science	1933	Anna Inskeep

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*Charter members.

MEETINGS OF RELATED GROUPS

Following the precedent of former years, the members interested in entomology and systematic botany held informal meetings at the fall meeting on Saturday forenoon, November 5.

Entomology.—The meeting was called to order at 9 o'clock by Philip Luginbill, chairman. Thirty-three attended this session.

Informal discussions took place on various subjects of interest to economic entomologists, such as Corn Earworm Investigations, by E. V. Walter; Cutworm Studies and Corn Borer Investigations, by G. A. Ficht; Forest Insect Investigations, by B. A. Montgomery; Hessian Fly Studies, by Curtis Benton; and White Grub Investigations by Philip Luginbill. All these discussions aroused considerable interest.

The latter part of the period was taken up by G. E. Gould, who showed some films on the development of cockroaches and activities of other insects.

P. T. Ulman, Indiana Department of Conservation, was elected chairman of the group for 1939.

Taxonomy.—The meeting of the plant taxonomists was called to order by Ralph M. Kriebel, chairman. About 40 attended the discussion.

The meeting was devoted to a symposium on the concept of the species, the discussion being centered about the following four topics: History of the Concept of the Species, by Theodore Just; The species Problem from the Standpoint of the Taxonomist, by Ray C. Friesner; The Use of the Species Concept in Mycology, by Marion L. Lohman; and The Genetic Interpretation of the Species, by Alfred C. Kinsey.

There was a report on the field trip held in the Kankakee region, Setpember 2-5, 1938, supplemented by Kodachrome slides of photographs taken in the field during the meeting.

It was decided to have another summer field trip in 1939 in southwestern Indiana. Scott McCoy and Chas. C. Deam were appointed as a committee to make arrangements.

Fred A. Loew, Huntington College, was elected chairman for 1939.

NEW MEMBERS 1938

Ackerson, Oscar E., 1711 O Street, Bedford.
Belcher, Robert Orange, 224 Waldron Street, West Lafayette.
Betz, Howard T., Valparaiso University, Valparaiso.
Biefeld, Dr. L. P., Purdue University, Lafayette.
Brundage, Roy Charles, Agri. Exp. Station, Purdue University, Lafayette.
Bryant, Carl C., 1312 Ferry Street, Lafayette.
Campbell, Dr. Kenneth Nielsen, 614 N. St. Peter Street, South Bend.
Cleland, Prof. Ralph Erskine, Indiana University, Bloomington.
Craig, Johnston C., 515 Lincoln Avenue, Bedford.
Daily, William A., 3216 Ralston Avenue, Indianapolis.
Danielson, Gordon Charles, Dept. of Physics, Purdue University, Lafayette.
Duncan, Robert Ferrie, 143 South Grant, West Lafayette.
Dutro, Miss Ruth, Hagerstown.
Echelbarger, Garold Hungerford, R. R. 1, Jonesboro.
Falkenberg, Dr. G. V., Purdue University, Lafayette.
Fitzgerald, Dr. Dorothea, St. Mary-of-the-Woods.
Fulwider, C. O., 617 W. Washington Avenue, South Bend.
Gantz, Dr. Edward S., 106 W. Jefferson Street, Crawfordsville.
Gasho, Miss Grace Anne, R. R. 2, Atlanta.
Gault, Hugh Richard, Ravinia, Illinois.
Geiger, Howard Eugene, Purdue University, Lafayette.
Hamill, Dr. William H., University of Notre Dame, Notre Dame.
Hartman, Dr. John D., Purdue University, Lafayette.
Henion, Miss Ruth E., Purdue University, Lafayette.
Hilbert, Miss Marguerite, 5868 N. New Jersey Street, Indianapolis.
Hines, George Ernst, Jr., Ulen Country Club Park, Lebanon.
Hopp, William Beecher, 1411 Maple Avenue, Terre Haute.
Hovda, Dr. Olaf, 519 S. Rotherwood Avenue, Evansville.
Howick, Prof. Harry, 403 N. College Avenue, Muncie.
Huffman, Mrs. Elna, 122 Waldron, West Lafayette.
Ignatia, Sister, St. Mary-of-the-Woods.
Johnson, Dr. David F., Indiana State Teachers College, Terre Haute.
Kase, John Charles, Purdue University, Lafayette.
Kent, Robert E., 198 State Street, Franklin.
Kesling, Robert Vernon, Peru.
Klinge, Paul Ernest, 3365 N. Colorado Avenue, Indianapolis.
Koepper, James M., Medora.
Lee, Hugh B., 1522 S. Center Street, Terre Haute.
Long, R. E., 604 Harrison Avenue, South Bend.
Longden, Grafton J., Jr., Broadview Farm, Greencastle.
Luginbill, Dr. Philip, 107 Fowler Avenue, West Lafayette.

Mauzy, Jack, 218 Pearl Street, Jeffersonville.
Maxwell, Dr. Roy D., Ball State Teachers College, Muncie.
Mitchell, Prof. Allan Charles G., Indiana University, Bloomington.
Murray, Herbert C., 106 W. Lutz Street, West Lafayette.
Overman, Richard R., Longden Hall, DePauw University, Greencastle.
Richards, Miss Ruth R., 3935 Graceland Avenue, Indianapolis.
Ryan, George S., 614 West South Street, Angola.
Serviss, Prof. Fred LeVerne, 136 East Stadium Avenue, Lafayette.
Shaw, Thomas Edward, 206 W. Lutz Avenue, West Lafayette.
Shockley, Clarence Herbert, 924 Woodlawn Avenue, Terre Haute.
Strickler, Dr. P. M., Indiana Central College, Indianapolis.
Summers, S. D., 514 W. Prospect, Angola.
Templeton, Miss Margaret, 898 E. Jefferson Street, Franklin.
Terry, Robert Lee, 6536 Irving Avenue, Merchantville, New Jersey.
Thomas, Dr. Ancil R., 831 Laporte Avenue, Valparaiso.
Thomas, H. Rex, Purdue University, Lafayette.
Thrun, Dr. Walter E., Valparaiso University, Valparaiso.
Tussing, Lyle, 619 Salisbury, West Lafayette.
Uyl, Prof. Daniel Den, Purdue University, Lafayette.
Van Camp, John Lloyd, 226 Lincoln Street, West Lafayette.
Wean, Robert Eugene, Purdue University, Lafayette.
Weimer, Dr. Harry Raymond, Manchester College, North Manchester.
White, Francis M., 6529 Woodlawn Avenue, Chicago, Ill.
Whitmore, Robert, Zionsville.
Wright, Dr. William Lee, 208 E. 46th Street, Indianapolis.

NEW JUNIOR CLUBS 1938

Junior Academy Club of University School, Indiana University, Bloomington.
Madison High School Science Club, Madison.

FELLOWS ELECTED 1938

Beghtel, Dr. F. E., Evansville College, Evansville.
Graham, Prof. F. V., Ball State Teachers College, Muncie.
Kriebel, Dr. Ralph, Soil Conservation Service, Bedford.
Smith, Dr. B. H., Indiana State Teachers College, Terre Haute.
Thornbury, Dr. W. D., Indiana University, Bloomington.

HONORARY FELLOW, ELECTED 1938

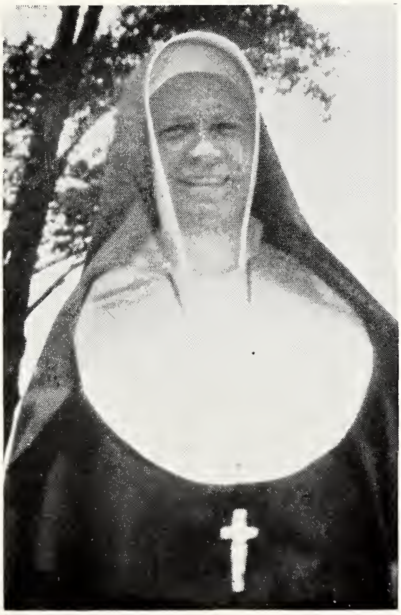
Arthur, Dr. Joseph Charles, Purdue University, Lafayette.

NECROLOGY

SISTER AMATA (ROSALIE MCGLYNN)

Chicago, Illinois — St. Mary-of-the-Woods
July 23, 1891 — April 2, 1937

For several years, Sister Amata McGlynn had linked her life with that of Saint Mary-of-the-Woods College. Particularly solicitous was she about the freshmen of Guerin Hall, whose training and direction, in her office as class adviser, she had eminently carried on. Their interests were her interests; their joys and sorrows were alike hers. Neither did her guiding influence cease with each succeeding class; it passed on continuously until each student gained senior rank and later on achieved a role in the drama of life. Sister Amata closely directed freshman extra-curricular activities, keeping always in view the highest ideals. In the scholastic calendar many events reveal Sister Amata as an organizer, a leader of exceptional merit.



SISTER AMATA

In the lecture room Sister Amata was a master in her fields—chemistry and mathematics. She, with knowledge at her finger-tips, was a teacher par excellence. In 1929, for her work in chemistry, she received the degree Doctor of Philosophy from Indiana University and was elected to the Society of the Sigma Xi. Closely associated with the Chemistry Department of the college, the Curie Club, composed of the majors and the minors in chemistry, found Sister Amata a competent director in its experimental work and its various lecture programs. Her scholarly interest disclosed itself also in her active memberships in the Indiana Academy of Science, the American Association for the Advancement of Science, and the American Chemical Society.—*From a memorial in the Saint Mary-of-the-Woods Alumnae News, 12:21-22. 1937.*

WILLIAM BEBB

Rockford, Illinois
June 15, 1869

Spencer, Indiana
April 7, 1938

Dr. William Bebb was one of a large family, many members of which had a deep interest in plant life. His father was known over the world for his work on the taxonomy of the willows, and many of the famous botanists of the time visited the Bebb home at Rockford, Illinois.

After graduation from the Chicago College of Dental Surgery, Dr. Bebb practiced his profession for a time in Chicago, but his broader interest in dentistry soon called him into the field of teaching and research. From 1902 to 1914 he served the Dental College of the University of Southern California as librarian, secretary, and teacher, began collection of material for a museum of comparative dental anatomy, and assisted in the reorganization of the Southern California Dental Association.

In 1914 he transferred to Northwestern University and undertook the development of the museum and library of the dental school. This work later took him to Europe, where he secured a large collection of books and engravings. This material, with other collections secured in America, forms the nucleus of the present museum and library of the school.

In his later years Dr. Bebb spent a great deal of time and effort in the development of a summer home near Lauderdale Lake in Wisconsin. His interest in the study of the interplay of native and introduced species and their environment led to his withdrawal from his position at Northwestern in 1927.

Later an opportunity was offered for him to continue his work as a naturalist at the McCormick's Creek State Park, near Spencer, Indiana, where he created the now popular Trail Side Museum. At the park he lived during the summer in a little group of tents, a model camp, with feeding stations for birds and small animals. It was only in camps like this that he was wholly at home and at his best, whether in Indiana, the High Sierras, California, Wisconsin, or elsewhere.

In his numerous trips to and from California he made extensive studies of the destructive effects of the automobile on bird and animal life.

The Dental Index of Periodical Literature lists Dr. Bebb fifty-one times, the greater number of his publications dealing with comparative dental anatomy. He also wrote many notes on various phases of natural history.—*Written from material supplied by E. H. Hatton, Northwestern University.*

KATHERINE GOLDEN BITTING

Stratford, Ontario, Canada — San Francisco, California
April 29, 1869 — October 15, 1937

Katherine Golden Bitting received her Bachelor of Science degree at Purdue, 1890, Master of Science, 1892, and Doctor of Science, 1935.

She was assistant botanist, Indiana Experiment Station, 1890-1893; instructor in biology, Purdue, 1893-1901; assistant professor, Purdue, 1901-1904; microanalyst, Bureau of Chemistry, U. S. Department of Agriculture, 1907-1913; technician, National Canners Association, 1913-1918; member, Subsistence Division of the Q.M.C., 1918-1919; bacteriologist, Glass Container Association, 1919-1923. She was fellow of the A.A.A.S. and the Indiana Academy of Science and a member of the Botanical Society, American Society of Bacteriologists, and the California Academy of Science.

KATHERINE GOLDEN BITTING

Dr. Bitting's adult life was spent in research. Her specialty was micro-organisms of preserved foods. She was a distinguished botanist and microanalyst, specializing on molds and micro-organisms involved in the preparation and preservation of food. In collaboration with her husband, Dr. A. W. Bitting, who survives her, also a noted specialist in foods, she published extensively on joint researches.

A list of research articles includes 45 titles ranging from papers in scientific journals to monographs and bound volumes. Her last manuscript, soon to be published, is a bibliography on gastronomy in which over five thousand publications in various languages had been considered.

This probably will be the most comprehensive work in the field. During her residence in this state, she was an active member of the Indiana Academy of Science and contributed numerous papers.

Dr. Bitting was a woman of rare wit and personal charm. She abhorred intellectual indolence and dishonesty in any of their forms, and her scientific work made her an authority in her chosen field.—*John S. Wright.*

CHARLES BROSSMAN

Philadelphia, Pennsylvania	Indianapolis, Indiana
January 17, 1887	June 30, 1937

After his graduation from the Philadelphia Manual Training School, Charles Brossman entered the employ of a manufacturer of scientific instruments. His next work, with the Baldwin Locomotive Works, in Philadelphia, was interrupted by service in the Spanish-American War with the Puerto Rican Expedition as a member of the First Troop, Philadelphia City Cavalry.

At the close of the war he moved to Indianapolis where he was engaged in the design of filtration plant and pumping equipment for the Indianapolis Water Company. At the same time, he had a responsible part in the construction of the filtration plant in Washington, D. C.

In 1904, Mr. Brossman entered the private practice of engineering, opening a consulting office in Indianapolis with Mr. R. P. King. This partnership was dissolved in 1907, and Mr. Brossman continued the consulting practice in his own name. His engineering work centered in the Middle West, notably in Michigan, Illinois, Iowa, Ohio, Kentucky, and Indiana.

As with most young practicing engineers, his earlier work had considerable variety, including design and supervision of construction of factory buildings, asphalt plants, street improvements, and heating and power plants. Gradually, however, as his reputation grew, he specialized in water supply and sewage disposal for cities, towns, and institutions. His career was stopped at its peak by his sudden and untimely death.

Mr. Brossman's activities were extended in generous service to his profession. In addition to his membership in numerous technical and business organizations, he was Secretary of the Indiana Engineering Society for twenty years, and, later, was President of that organization. He also served at various times as an officer of a number of other professional societies.

Not satisfied with his contributions to the up-building of his profession, Mr. Brossman was the author of many articles in the public and technical press, in the publications of the organizations of which he was a member, and of numerous papers presented at engineering meetings. The Ohio Valley floods in January, 1937, added to his burden of engineering engagements, but he still found time to prepare articles for publication on flood-control measures in Indiana.

His interests were by no means confined to his professional work but were carried into the life of the community in which he made his home. At the time of his death, Mr. Brossman was Chairman of the

Boys Work Committee of the Indianapolis Rotary, an incident in his busy life, but in itself indicative of his widespread interest in the people about him.

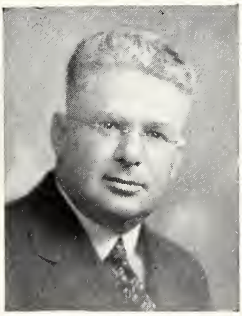
Socially, he was genial companion, possessed of a rare sense of humor and full of sparkling fun. A man of unimpeachable integrity, his code of professional ethics was exceptionally high. His varied interests and his willingness to serve made him an unusually active and useful citizen, as well as an honor to his profession.

In 1903 he was married to Mary Edith Dean, of Indianapolis. His widow and three children, Charles Dean Brossman, Mrs. Francis (Brossman) Meyer, and Mrs. Frank (Brossman) Parish, survive him.—*Condensed from Memoirs of the American Society of Civil Engineers.*

FRED DONAGHY

Ossian, Indiana — Terre Haute, Indiana
March 3, 1879 — July 8, 1938

Fred Donaghy was born on a farm near Ossian, Indiana, on March 3, 1879, and died while in service as Professor of Physiology and Hygiene at Indiana State Teachers College on July 8, 1938. He received his elementary education at Ossian and graduated from the high school in 1898. Shortly thereafter he entered the Indiana State Normal School at Terre Haute and, after receiving sufficient training, became a teacher in the elementary schools of Indiana.



FRED DONAGHY

Upon graduation from Indiana State Teachers College in 1912 he was honored with a scholarship at Indiana University and received his Master's Degree from that institution in 1915.

Shortly after his graduation from Indiana State Teachers College, he became connected with that institution as instructor, and, save for the time that he was on leave of absence pursuing graduate work and in the service of the United States army during the World War, he remained there until the time of his death, serving as instructor, assistant professor, associate professor, and professor of biology and physiology. During the last ten years of his professorship he was in charge of the work in physiology and hygiene, and in that capacity he endeared himself to a great number of young men and women who were entering the teaching profession and the field of medicine.

In 1926 he secured a leave of absence from the institution to accept a fellowship at Johns Hopkins University and work toward the doctorate. The degree was conferred in 1928, and Dr. Donaghy returned to continue his work as professor of physiology and hygiene.

Dr. Donaghy's dissertation for the master's degree, "The morphology of Riccia fluitans," was published in the Proceedings of the Indiana Academy of Science in 1916, and that for the doctor's degree, "Studies in immunity to transplantable tumor," was published in 1930 in the American Journal of Public Health.

While at Johns Hopkins University he was elected to Sigma Xi. He became a member of the Indiana Academy of Science in 1918 and was elected fellow in 1930.

Dr. Donaghy was known to his colleagues and his students as a sincere teacher and an untiring worker. In addition to the work which he carried on as professor of physiology he was a tireless worker with flowers. At the time of his death he had two beautiful gardens at North Terre Haute in which he spent all of his spare time, and it was while working in one of these gardens that the attack resulting in a cerebral hemorrhage occurred.

It may be said without exaggeration that the death of Dr. Donaghy was one of the most severe shocks Indiana State has had in recent years. In addition to being a great teacher, he was a great leader of young men and women. There are hundreds of young people in Indiana and throughout the United States who will remember him and cherish his excellent advice and words of encouragement. He was instrumental in procuring scholarships and fellowships in leading universities for many young men in his classes. A great many of these young people were helped not only in a spiritual manner but in a financial manner as well. Dr. Donaghy spent a great part of his salary on the two hobbies in which he was interested, his garden and young people.

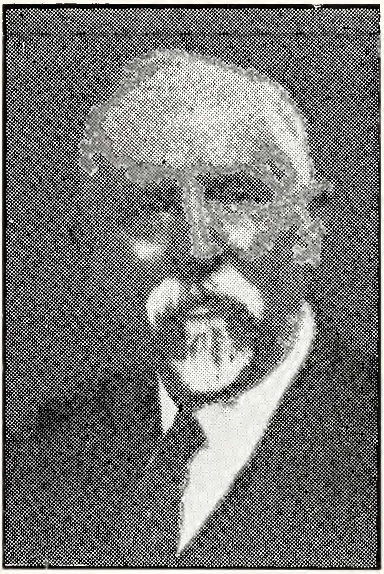
His spirit will live on in Science Hall at Indiana State, where he is now commemorated by an inspiring mural in the main hall painted by one of his most ardent admirers, Gilbert Wilson.—*James F. Mackell.*

JOSEPH P. NAYLOR

Pennsville, Ohio | Little Rock, Arkansas
April 4, 1853 | May 22, 1938

With the passing of Professor Joseph P. Naylor at Little Rock, Arkansas, the Academy lost one of its few remaining charter members and one of its past presidents. Professor Naylor was born near Pennsville, Ohio, but came to Indiana early in life. Receiving the master of science degree from Indiana University in 1885, he was a professor of physics from 1885 to 1891. He became head of the Department of Physics at DePauw University in 1891, when DePauw was the largest university in the state, and remained until his retirement as emeritus professor in 1925. During the past few years he lived with a daughter in Little Rock, Arkansas. Another daughter also survives him.

Professor Naylor was a man of fine personality and broad interests. A trained and skillful technician, he constructed much fine and delicate apparatus most of which is still in use at DePauw today. Deeply interested in botany, he made a fine collection of mosses which he presented to the Department of Botany at the time of his retirement. As an excellent and inspiring teacher, he trained a number of students who have since become outstanding in physics. He was active in church work and was director of a church choir for many years.



JOSEPH P. NAYLOR

As long as he remained in Indiana Professor Naylor was active in Academy affairs, serving as president in 1912. He was a founder and a president of the Indiana Association of Physics Teachers, a member of Phi Beta Kappa, and a fellow of the American Physical Society.

Joseph P. Naylor was one of that splendid group of early Indiana scientists which included David Starr Jordan, John M. Coulter, John C. Branner, and Harvey W. Wiley, and in his death Indiana loses another one of its distinguished men who contributed much to the scientific progress and standing of the state.—*Will E. Edington.*

PRESIDENTIAL ADDRESS

A Plan for Accomplishing More Effective Research

ELI LILLY, Indianapolis

It takes a large amount of self-assurance for a person who has nothing more on his watch chain than a magnifying glass to attempt, in the words of a picturesque Hoosier idiom, "to teach his grandmother to suck eggs," and yet, certain experiences in the executive direction of some important pieces of research and the exigencies of the occasion possibly justify his taking some liberties.

In January of this year, an investigation on "Creative and Research Work in the Undergraduate College of Liberal Arts," conducted by DePauw University, revealed that in two-thirds of sixty-five of America's most important educational institutions conducting investigations of an advanced order, there were no central committees to consider and coördinate the work. In the remaining third, it is quite evident that in only a very few cases was the vital importance of proper coördination and coöperation recognized.

In the great majority of colleges, research is carried on by what might be called the "Departmental Pigeonhole System," that is, a single able professor with a few assistants and a small number of students bury themselves in the gloomy recesses of a single department, heedlessly avoiding the sparkling sunlight of collateral branches of knowledge and the cross-fertilization of ideas from the pollens borne on the fragrant breezes of the upper air. Rarely, if ever, can an investigation be properly confined to problems within the scope of a single department, and yet, in an overwhelming majority of cases we find pieces of research being planted amidst bleak surroundings where one or several life-giving elements vital to its full-flowering are sadly lacking.

The Departmental Pigeonhole System was at its highest peak in the days of the alchemists who worked in secret and kept their records in private codes, thus greatly delaying important chemical discoveries.

In China, a man who has a limited amount of knowledge is compared to a person sitting at the bottom of a well; the sky appears very small to him. In the ramification and specialization of modern sciences, we who specialize in one well find ourselves much in the position of the Chinese gentleman—our lines of vision do not diverge much from the mouth of our own particular well. It is necessary, therefore, that we join hands, pull ourselves to an elevated level, and see the horizon.

The logical way of starting an inquiry in any organization is to call together an enthusiastic group of men who know about the subject from as many viewpoints as possible. When this is done, scant respect can be paid to chilling academic departmental boundaries, but the brilliant results of such coöperation speak for themselves. Who would expect a surveyor to make a map if he were required never to move from one spot? It is just as reasonable to expect to explore thoroughly a complicated question from only one direction. Yet how great is the majority of research workers who have ignored this perfectly apparent truth. It has been a blind spot in our procedures.

Securing effective joint action between investigators in different departments calls for an excursion into the humanities. It cannot be accomplished by cracking together the heads of research men with the peremptory command, "Coöperate!" It requires long and careful preparation and presupposes that the head of the university is sympathetic to scientific inquiry and commands the respect and loyalty of his deans and that they have confidence and trust in one another, in short, that the *esprit de corps* of the institution is high. Unless you have this firm basis to build upon, time and effort will be wasted.

It is not as though coöperation were a brand new project with this Academy, for our Biological Survey may be mentioned as a successful instance of the value of working together. At the Indianapolis meeting of the American Association for the Advancement of Science last December, there was evident a heartening tendency for the various sections of the sciences to consult and advise with one another.

Dating by tree rings, to the very year of the building of a great number of the pueblos in the Southwest, is a most outstanding and brilliant example of the coöperation of astronomers, botanists, meterologists, and archeologists.

The spirit of joint participation in well-planned research has been brilliantly developed in the great organization that we have the honor of visiting today. The morale of its staff has been of the highest order for years, so the proper elements for the development of coöperative work were present. Ten years ago the Purdue Research Foundation was formed and was fortunate enough to secure the services of a "catalyzer" who knew his humanities and under whose careful nurture the plant has grown to symmetrical and beautiful proportions.

At the beginning, a delicate touch was required, and the first activity was simply a survey which revealed that the faculty were conducting a surprising number of worthy projects, the existence of which had been hitherto generally unknown. Some of these pieces of work were more or less duplications, and there were frequent overlappings. Adroit and sympathetic suggestions with a sprinkling of spiritual and financial encouragement extending over a period of months was all that was needed to convince the staff that great good follows the liberal and generous exchange of ideas in research work. Since the professorial staff must be the inspiration of all original work, care was taken not to invade the chosen fields of professors who had long been conducting successful investigations. Their work was reënforced by additional funds and encouragement. The Purdue Research Foundation has grown to be one of the most successful centers of research in the country.

An objection might be raised as to the great difficulty to be encountered in the proper division of scientific credit and of financial return in coöperative work. We are apt to build up in our minds the horrid image of a flashing sword poised above the research baby in a desperate effort to discover its real parent. This is a bogey easily banished by mutual confidence and fair and impartial supervision. Under such conditions it has proved to be a trivial danger as compared with the great gain in power of accomplishment. The allocation of credit has long been solved by scientific men by the lists and order of their names upon publications. Even in cases where temporary misunderstandings have been engendered, time, the great impartial umpire, has given the credit to whom it was due. The public cannot be fooled forever.

The division of financial returns resulting from royalties is handled in several ways by different universities. In a few, as in Harvard, nothing is patented and no royalties taken. This policy seems a wasteful one, for royalties create a fund for financing further inquiries. In some institutions, like the University of California, the attitude is to leave the University out of consideration altogether and to allow the professors to take out patents and handle the royalties as they see fit. In an increasingly growing number of research centers, however, the royalties are being used for further investigation. In the case of a university research organization, a very fair division would be: one-third of the royalty to be given the personnel involved, one-third to be plowed back into the general research fund, and one-third to be used for further work upon the project yielding the royalty.

While admitting the value of allied work in research in the applied sciences, a very natural mental reservation might occur as to its possibilities in original work in other fields. This doubt may be dispelled by a review of the usual departments found in leading universities and colleges. Take for instance philosophy, psychology, religion, political science, and political economy. Each one of these branches of knowledge should be used, individually and collectively, to triangulate upon the most vitally important questions of the day. Combined, they would be much stronger than if used alone—remember the old fable of the bundle of sticks.

Again the question might be raised as to what chance any of such studies have to gain financial encouragement, especially from business institutions. The answer is that the opportunity is here, or should be, for what is more important than the manifold personnel problems that face our civilization? Forward-looking businesses are employing psychologists and psychiatrists to develop the understanding of executives and to reëducate faulty reaction-mechanisms in individuals needing it. The one most important duty of the head of any organization is to develop and to stimulate the human material within it, for if the personnel is able and enthusiastic and of high morale, the work of the institution takes care of itself. Its success is assured. If its human material is not happy and enthusiastic and is ill-trained and dull, nothing on earth can save it. Do we dare say there is no chance for collaboration in research here?

That our spiritual development has a hundred-year lag behind our material progress is a trite statement. Several years ago Edward Filene, of Boston, warned business with the pregnant words, "Research or Bust." Are not the same words appropriate for those of our educators and religious guides whose efforts are so far behind the times? They need all the power they can borrow, beg, or steal to stem the tide of materialism engulfing the world and to teach all humanity that it is not what we have but what we are that is of real importance. We must be taught that the imponderables are vital—radiant personality, intense love of fine and beautiful things, honor, courtesy, etc. Our attention must be taken from the gross, materialistic philosophy which occupies so many today to the exclusion of practically everything else. Greed in all quarters (and it *is* found in *all* quarters) should be attacked by the most powerfully allied groups of authorities that can be called to the colors. No chance for a coalition of talent here? Why, the very sky is the limit! Much important work along these lines is going on at the University of Iowa, but theirs is almost a voice crying in a dismal wilderness.

Let us mention a few other subjects selected almost at random, such as, law, sociology, history, languages, literature. There is not one of these fields which cannot be enriched by knowledge and insight gained from the others. Mathematics is the background and final arbiter in almost any field of knowledge. Not long ago I heard an outstanding scientist say that Dr. Irving Langmuir could prove mathematically what most highly trained men could just barely imagine!

The pioneer work of the Purdue Research Foundation has been followed very closely by Ohio State at Columbus. The Wisconsin University Departments of Medicine, Agriculture, and Chemistry have proved the great value of working together upon many of their problems. At the University of Iowa the spirit is growing, and we are wondering what relationship this spirit has to the notable development of a new school of American Art there. The Harvard Medical School is concentrating upon the problem of proper coördination in its pioneer work.

The next step in the "orchestration" of research will be the pooling of efforts by separate organizations. This will be more difficult than winning success in the various individual institutions. Let us hope that it will never be carried as far as by some individuals and universities in some foreign nations, where to every intent and purpose some center announces that its members are working in a certain field and all outsiders are warned not to trespass! In the coöperation of twelve of our agricultural schools in the cultivation of corn may be seen the dawn of this further coördination of experimental work. The Northeastern Agricultural Experiment Stations have appointed each director a referee for the guidance of investigation in one field. In astronomy, more perhaps than in any other field of knowledge, due to the relatively small number of important centers, the research work is organized, coördinated, and unified.

For more than a century, Indiana has been associated with men eminent in science. The founders of this Academy included a number of international fame in their respective fields. During the last fifty years, members of this organization have done much to enlarge the boundaries of knowledge, and there is enough high talent in this room today, if thoroughly coördinated, to cause Indiana to become a "center of white-hot spiritual energy." The free exchange of opinion, interaction of imagination, cross-fertilization of ideas, and the pooling of wisdom will cause the maximal utilization of human effort, the elimination of unnecessary duplication, and a great increase in results. Properly coöperative research work is synergistic and does not increase in success by arithmetical but by geometrical progression. Steps to secure its adoption by our educational bodies is the one greatest opportunity lying before us.

SECTION ON ARCHEOLOGY

Chairman: Glenn A. Black, Indianapolis

The attendance at the meeting was small, and this has raised, in the minds of those interested in the section, the question of enlisting the support of many non-professional students of archeology and anthropology. It is believed that the "hunch of the amateur" may often lead to the solution of technical problems.

Of prime interest to archeologists of Indiana is the announcement that the Indiana Historical Society has, through purchase, saved from destruction the most famous archeological site in Indiana, namely, the Angel Mounds, located a few miles east of Evansville. It is planned at an early date to explore the site and to restore the mounds, as far as possible, to the condition in which they were occupied by the Indians.

Mr. Paul Weer, who is engaged in ethno-historical work for the Indiana Historical Society, was elected chairman of the section for the coming year.

ABSTRACT

The present status of archeology east of the Mississippi. Glenn A. Black, Indiana Historical Society.—The taxonomic method of dealing with archeological cultures has done much to clarify problems of the past. The Mississippi Pattern, with the exception of a postulated Lower Phase, is now rather well defined. The Woodlands, in the Northeast, has been defined for a period suggesting considerable antiquity. In the north central region, the pattern at present appears to apply mainly to tribes of more recent occupation levels. The third pattern, as yet unnamed, presents a far more obstinate problem. Hopewellian, its principal phase, has been and continues to be the bane of all workers in this field. Culturally suggesting a transmutation of Mississippi and Woodlands, the diagnostic traits of each are such as practically to defy relegation. Mississippi traits within the phase are neither Upper nor Middle Mississippi determinants. The Woodlands elements, with the exception of ceramics, do not seem to match too closely those traits defining the Lake Michigan Phase of Woodlands or the aspects within this phase.

As a working hypothesis the suggestion is made that (1) Hopewellian is basically Woodland with many Mississippi elements within it which are neither Upper nor Middle Mississippi; (2) the Mississippi traits within Hopewellian are, in part, diagnostic of a deep south culture group, the identity of which has not yet been made clear; (3) the Woodland traits within Hopewellian, combined with those for the Lake Michigan Phase of Woodlands, will provide a sorely needed chronology and depth for Woodlands within this area; (4) the Copena Complex as found by Webb, the Marksville of the Southeast, and investigations now being carried on in the Gulf region will go far toward solving the question of origin of many elements within the Ohio and Elemental Aspects of Hopewellian. Adena and Hopewellian are far more homogeneous than their present relative placement within the classification indicates. Adena should be considered as a direct aspect of Hopewellian rather than in a separate phase category. Adena, occurring repeatedly at components also productive of Fort Ancient, raises the query as to whether Adena-Hopewellian is late enough and Fort Ancient early enough for there to have been some slight degree of tangency between them. It should be made clear that these suggestions are yet to be tested. Concerted action, resulting from the elimination of the personal element in research, standardization of nomenclature, and systematic classification of culture traits is, however, making such suggestions acceptable to a group, whereas a few years since they would have been considered heretical.

Some Possible Sixteenth and Seventeenth Century Locations of the Shawnee

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Due to the indefinite character of the term *šaawanwa*, which the Shawnee[1] apply to themselves as a tribe, it is extremely difficult to locate the Shawnee with any degree of certainty during the early colonial period. In many Algonquian dialects the Shawnee tribal name *šaawanwa* has cognates meaning "south" or "southerners"; therefore, when Algonquian-speaking peoples refer to a group by a term approximating *šaawanwa*, it is an open question as to whether the Shawnee are meant, specifically, or whether the reference is merely a generic one, applicable to any Algonquian group or groups located to the south of the main body of this stock. In our estimation, however, it seems likely that the name *šaawanwa* or approximations thereto specifically relate to the Shawnee in the majority of our early references. Not only do the Shawnee recognize *šaawanwa* as their tribal name, but various Algonquian and non-Algonquian groups, as well as the English, French, and Spanish, use terms approximating *šaawanwa* in reference to the Shawnee.

Since Mooney sounded his warning note as to the uselessness of theorizing on the location of the Shawnee prior to 1669-70,[2] a certain amount of new data has appeared which merits discussion as possibly indicating some locations of the Shawnee during the period 1540-1670. These data I wish to review as briefly as possible.

1540.—Evidence for one possible location of that part of the Shawnee tribe known as the *čalakaaθa* division is contained in the accounts of De Soto's expedition of 1539-44. While still east of the Blue Ridge, and probably near the headwaters of the Savannah river in what is now western North Carolina, De Soto and his party visited the province of Chalaque. The province was poor and lacking in corn; the inhabitants gathered roots and herbs and shot game with bows and arrows. The people were naked, lean, and unwarlike, and one town in the province gave De Soto's party 700 wild turkeys, with which the country abounded. A chief gave De Soto two deerskins. Garcilaso states that all the "Chalaques" save the old and the blind left their towns when De Soto's party approached and fled to the mountains.[3] Mooney and other historians have identified the "Chalaques," "Chelaques," or Achalaques as the Cherokee.[4] Concerning the identification of Chalaque, however, Swanton has recently offered an interesting commentary. He says, "It has been usual, and natural, to identify the Chelaque or Xalaque of the De Soto chroniclers with the Cherokee, but if the word Cherokee has the origin I suspect, from Muskogee chilokee (there is no *r* in Muskogee), signifying 'people of a different speech', it may not have been applied solely to the Cherokee but as well to other non-Muskogee tribes, such as the Catawba and their allies. If that is the case, the use of the term in the De Soto chronicles does not prove that the Cherokee were then in their historic seats.[5]

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[1] The Shawnee are an Algonquian-speaking group prominent during the 18th century in the Ohio Valley region. The tribe comprises five non-totemic, named divisions, to-wit: *calakaaθa, θawikila, mekoce, pekowi, and kispoko.* Linguistically the Shawnee are most closely related to Kickapoo, Fox, and Sauk. The Shawnee now number about 1,500 souls, including mixed bloods; they live in three groups in central and northeastern Oklahoma.

[2] **12**, p. 531.

[3] **10**, p. 24.

[4] **10**, p. 194; **22**, p. 204.

This statement by Swanton suggests, of course, an interesting possibility concerning the derivation of the name for the *čalakaaθa* division of the Shawnee. Part of this term, *čalakaa*, is unanalyzable in Shawnee and may represent, in borrowed form, the Muskogean term *Chilokee;* the *θa* formative ending of the term is a formal Shawnee suffix designating "an individual or collective individuals."[6]

Swanton's remarks also make worth consideration the possibility that it may have been the *čalakaaθa* division of the Shawnee which De Soto encountered in western North Carolina in 1540. This supposition is admittedly based on slender evidence, but it receives some measure of support from Shawnee traditions, certain of which assign a definite southeastern origin for the *čalakaaθa* division. The description of the people in the province of Chalaque would fit the Shawnee, who lived a part of the year in villages and raised small crops of corn but were essentially hunters and gatherers; however, the description is too general and might be attached with equal plausibility to too many other groups to be of any great aid.

1584.—In 1584 the chronicler for Raleigh's first colony mentions a "greate towne called Chawanock"[7] northwest of Roanoke on the Chowan river in northeastern North Carolina. The location of Chawanock was, it might be noted, a scant 400 miles northeast of De Soto's province of Chalaque. In 1585 some of the men from Raleigh's second colony at Roanoke visited "Chawonock" and reported it as "the greatest province upon the [Chowan] river, and the town itself can put 700 men into the field, besides the forces of the rest [i.e., of the towns subject to Chawonock]. The King is lame, but hath more understanding than all the rest."[8] In 1606 and 1608 Capt. John Smith and some of his colonists also visited Chawonock[9] and in 1608 Smith writes, "Master Sicklemore well returned from Chawwonoke. . . . The river he saw was not great, the people few, the country most overgrown with pynes. . . . But by the river the ground was good and exceedingly furtill."[10] In 1621 Sir Frances Wyat, Governor, also "travelled to the South River Chawonock, some 60 miles overland from Jamestown, which he found to be a very fruitful and pleasant country, yielding two harvests in a year . . . was kindly used by the people and so returned."[11]

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[5] 22, p. 204-205.

[6] The same suffix is added to the names of two other Shawnee divsions, *pekowi* and *kispoko,* to denote "person(s) of pekowi," "person(s) of kispoko." I never heard it added to the names of the *mekose* or *θakiwila* divisions, however.

[7] 18, p. 3.

[8] 18, pp. 5-6.

[9] 18, pp. 25, 87.

[10] 18, p. 87.

There seems little reason to doubt that the term *Chawanock* or its equivalent is used in the above reference to designate an Algonquian tribe or confederacy, the name for the group being taken from the main village settlement. In the brief sketch of the Chowanoc in the Handbook it is recorded that the tribe "gradually dwindled away before the whites, and in 1701 were reduced to a single village. . . . They joined in the Tuscarora war against the whites in 1711-12. . . . In 1820 they were supposed to be extinct."[12] Our entire information concerning the Chowanoc is limited to some twenty historical references. No mention is made to a part of the group moving from their seat on Chowan river; yet, when we consider the differences in population noted for the Chowanoc in 1585 and 1608, the withdrawal of a part of the tribe becomes an interesting possibility. As to the connection of the North Carolina Chowan with the Shawnee, we were until recently inclined to minimize the possibility of any such linkage, because the names of several Chowanoc villages bear no resemblance to any names one might expect for Shawnee villages, which were customarily designated by the same name as the division occupying them. However, in C. C. Trowbridge's manuscript account of the Shawnee (1824), the Shawnee Prophet states that the tribe formerly comprised six divisions, that the proper name for the sixth was Shawano, and that it was formerly a leading division of the Shawnee but had been extinct for some time. The Prophet supposed that the tribal name was derived from the name for this extinct but once powerful division.[13] If this division had any connection with the now extinct Chowanoc, we have here a valuable link in the chain between various southern and northern groups of Shawnee. I have at this time no other evidence to offer on the question. Before discussing the next possibility, which is concerned with one of these dubious northerly groups, I should like to point out that the Chowanoc of North Carolina may be the tribe referred to in the Delaware record of the Walum Olum as departing to the south lands together with the Nentegos (Nanticoke).[14] The withdrawal of the Nentegos and "Shawanis" is generally interpreted as having occurred before the Algonquians reached the eastern seashore; granting this interpretation to be correct, it is of interest to find, in the historic period, a group known by a term approximating *Shawanis* at no great distance south of the Maryland Nanticoke.

1614.—We now come to an extremely interesting problem—that of the possible identity of a group referred to on the Dutch Carte Figurative for 1614 as "Sauwanew", located on the east bank of the Delaware river near its mouth, in New Jersey.[15] In 1634 De Laet mentions the "Sawanoos" as living in the vicinity of the Delaware river,[16] and a few years later the "Sauwanoos" and "Sauwan" are mapped as being located west of the Delaware, between that river and the Susquehanna in eastern Pennsylvania.[17] Mooney sees no reason for considering any of the above terms as applying to the Shawnee proper; he gives as evidence (1) that, in 1646, the Shawnee do not appear either in Ruttenber's or Evelin's lists of northern and southern New Jersey tribes, and (2) that the term *Sauwanoo* was used by the Dutch as a generic term for "southerners", in the same way that *Wappanoo* was used for easterners.[18]

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[11] 18, p. 143.

[12] Mooney (11).

[13] Trowbridge (21).

[14] 3, p. 204, song V, line 10.

[15] 14, vol. 1, pp. 11, 13, and maps.

[16] 8, p. 82.

Mooney's interpretation of the New Jersey data is not convincing. The terms *Sauwanoo* and *Wappanoo*, or their equivalents, are not only used as generic terms by Algonquian groups but are also, as we have seen, applied to specific groups as well. We have noted the use of Chowanock for a specific North Carolina group, and at the present time the Shawnee themselves refer to the Delaware group now located near Anadarko, Oklahoma, as *wapana'ki* or "easterners", meaning by this term one specific Delaware division.

In regard to Mooney's other objection, the lack of mention of the Shawnee in New Jersey lists of 1646 is not surprising. By this date the Shawnee had, in all likelihood, moved considerably west or south of the New Jersey location. Troubles with the Dutch colonists, who attempted to settle on the lower Delaware river before the arrival of the Swedes in 1638, or with the Seneca and related groups who were beginning to obtain guns from the English and Dutch traders, may explain the removal; if the New Jersey-Eastern Pennsylvania Shawnee were a part of the North Carolina group, they may have removed directly southward to rejoin this group.

An additional bit of corroborative evidence for the presence of a Shawnee group in the north early in the 17th century is contained in the Narrative of Hendrick Aupaumut, an educated Mohican, writing in 1791. Aupaumut states, "The Shawannese, who we called Weshauwonnoow, are our [Mohican] younger brothers according to ancient covenant between our forefathers—for our ancestors, near 200 years ago rescued them from the mouth of many nations, as well as of the Five Nations who were ready to swallow my younger brother Shawany, for which kind deliverance they ever have felt themselves under the greatest obligation to obey our voice—and many nations had knowledge of this."[19] Whether Aupaumut's dating is reliable is open to question; that the Mohican befriended the Shawnee as he states is well authenticated,[19a] and in 1694 some Shawnee joined the Mohican tribe.[20]

An indication that the French had been informed of the presence of a Shawnee group in the northeast is found in a remark in Ragueneau's relation for 1651-52, "Another [Father] set out [from Quebec] with five or six neophytes in little bark Canoes, to go to the shores of Acadia and, by that route, find an easier approach to the tribes called Etechemins [Malecite], Abnaquiois [Abnaki], Sokoquiois [Sokoki], Sourikois [Micmac], Chaouanaquiois [Shawnee] . . . and numerous other savage nations, which are sedentary, and have villages of a thousand or two thousand fighting men."[21]

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[17] **13**, p. 170; **6**, vol. 1, p. 119; **19**, pp. 42-3, 46-7, maps.

[18] **12**, p. 531.

[19] **1**, p. 77.

[19a] **17**, pt. 6:277-8.

[20] **12**, p. 532.

Certain indirect evidence should also be considered. When part of the Shawnee moved north to the Susquehanna and Delaware river region at the close of the seventeenth century, they seated themselves in the same location that the Dutch maps for the early part of the century accord the Sawanoos.[22] The aid rendered by some of the Shawnee to the Andaste (Susquehannocks or Conestoga of the Susquehanna river) against the Iroquois prior to 1672[23] also indicates a probable early intimacy between certain Shawnee groups and tribes of the Delaware-Susquehanna region.

1625-1670.—For the period 1625-1670 no records have come to light of actual encounters by white traders, explorers, or missionaries with any group the name for which we can, with some degree of plausibility, associate with the Shawnee. Hearsay reports for this period concerning various Shawnee groups are fairly numerous and often contain conflicting statements; an attempt to evaluate their reliability would necessitate extended discussion. One point emerges with increasing clarity as the period 1625-1670 draws toward a close; this is the fact that by 1660 Shawnee groups were carrying on what appears to have been a lively trade with the Spanish in Florida. Father Lalemant, in 1662, mentions Shawnee captives' accounts of trading with persons whom the French judged were Spaniards.[24] In 1671 Marquette also refers to Shawnee-Spanish trade.[25] In 1674 Henry Woodward, interpreter for the South Carolina colony, met two Savana Indians who "brought Spanish beads and other trade as presents makeing signes yt they had commerce w^th white people like unto me, whom are not good."[26] Nine years later we have La Salle's statement that he has invited a Shawnee group to discontinue commerce with the Spaniards and establish residence on the Illinois river.[27]

From this brief review of the early literature, we have found evidence indicating the possibility of the Shawnee having been located in western North Carolina, northeastern North Carolina, southern New Jersey, and eastern Pennsylvania, during early historic times. The totality of the evidence suggests a more easterly location for the Shawnee during the early period of white contact than has generally been assigned this tribe.

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The Muskhogean Indians

Paul Weer, Indiana Historical Society

The Southeast aboriginal culture area extends over southeastern United States from the Atlantic Ocean to eastern Texas and from the Gulf of Mexico north to the Ohio River.[1] In 1700 the English and French found the Muskhogean Indians predominant in this great area and the leading tribal groups in our present states of Georgia, Alabama, Mississippi, northern Florida, and western Tennessee. One hundred sixty years earlier when De Soto made his famous march through the Southeast, he practically skirted the protohistoric boundaries of Muskhogean territories. If, instead of turning to the Southwest after leaving the South Carolina mountains, De Soto had journeyed northwesterly on through to the Ohio River, then westward to the Mississippi and south along that river, much light might have been focused on the mystery still obscuring the prehistory of the Ohio River Valley. The objective of this paper is to suggest the probability that between De Soto's time (1540) and 1700 Muskhogean-speaking tribes were in the Ohio Valley and were probably residents of southern Indiana.

Muskhogean-speaking Indians, believed to have been a brachycephalic, hypsicephalic physical type people[2] and members of the Hokan-Siouan linguistic stock,[3] entered the southeast area from the west long enough prior to the earliest Spanish contact (1513?) to have built permanent towns (many of them fortified) in the midst of fertile fields, producing a wide variety of agricultural products.

It is not known precisely when and from where they came, but their late traditions show that they journeyed from the "back-bone of the world," which have been interpreted to mean the Rocky Mountains. All of their early traditions, when a route was specified, indicated that they came east *via* the Red River Valley. There are also intimations that some few arrived from Mexico at a very late period.[4]

Archeologists have not reached that degree of knowledge essential to speak of Muskhogean material cultures, but rather as yet, of cultures found in Muskhogean territories. The Southeast area is predominantly Mississippi Pattern in its material culture manifestations. Some evidence of the presence of Woodland culture peoples, or at least of Woodland material culture influence, is found. Whether this represents pre-Muskhogean groups or was intrusive is not known. Indeed, the material culture characteristics of the earliest arriving Muskhogeans are not known; but in the course of time they made great contributions to the high cultural attainments later characteristic of the Southeast, which in many respects rivaled the great civilizations created in the Southwest area and in Mexico.

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[1] Swanton, 1935, p. 373.

[2] Dixon, 1923.

[3] Sapir, 1929, p. 139.

[4] Adair, 1775, p. 195; Le Page Du Pratz, 1763, II, 112.

Archaeological research has not established an accurate estimate of Muskhogean contributions to the Southeast material culture. Along with the basic need for more excavation, a principal contributing factor is that the northern boundaries of prehistoric Muskhogean territories are not known. If it can be established that Muskhogean, or probably to be more correct, proto-Muskhogean groups were resident in the Ohio Valley and were responsible for some part of the Middle Mississippi Phase material culture found there, it will greatly aid the assignment of Muskhogean traits known in the South.

An illustration of the coördination of tradition, language, and history on this subject is afforded in the case of the Alabama,[5] a tribe which in historic days was second only to the Muskogee themselves among the upper Creeks. Creek tradition says that when the Muskogees were trying to catch up with the Alabamas during the journey to their later homes, they found themselves at one time on the banks of the Ohio near the Wabash River. The length of the time duration of this sojourn is not indicated. De Soto, during the month of April, 1541, left the Chickasaw and set out toward the Northwest and on into the present state of Arkansas for a province called Alibamo. The Alabama and their close allies, the Tuskegee and Koasati, spoke a language dialect which was much closer to the Choctaw-Chickasaw language than to the Creek. The inference is that in 1541 some Alabama bands were living in Arkansas northwest of the Chickasaws where they had been in contact with Chickasaw groups long enough to have acquired or to have continued to retain the latter's speech and that sometime after 1541 they had moved northeastward to the Ohio and from there southward to their historic seats. Sometime between 1541 and 1673 the Siouan Quapaw moved into the Arkansas territories, for there they were found by Marquette in the latter year and by La Salle in 1681.[6]

The historic territories of the Chickasaw were in western Tennessee and northern Mississippi. Traditional and historical sources indicate that some of their people were dwellers in the Ohio Valley, both in early and late times. Traditionally, the Chickasaw and Choctaw came from the West as one family. This early relationship is confirmed linguistically in the close similarity of the Chickasaw dialect to Choctaw. According to tradition, after wandering away from the Choctaw, some Chickasaw groups went to the North as far as the Ohio River where they stayed for a short time and then returned to their own people. Historically, they are known to have had a colony on the lower courses of the Tennessee River (i. e., in northwestern Kentucky), and "in comparatively late times a small body settled temporarily on the Ohio."[7] The Chickasaw were in contact with dolichocranial groups to their north to the extent that brachycranial characteristics were in the course of time considerably altered.[8]

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[5] Swanton, 1922, pp. 191-93.

[6] For a summary of this problem see Weer, 1937, p. 117.

[7] Swanton, 1922, p. 419.

[8] Swanton, 1928, No. 1, p. 677.

The word "Muskogee," from which was derived the linguistic family name, is not a Muskhogean word at all; and no Creek knew its meaning. It probably came from the Algonkian tongue and meant "swamp" or "wet ground," first to be used by the Shawnee to identify a Creek tribe. The appellative "Creek" is of English origin, first used by South Carolinians to designate a tribe living on Oconee Creek, Georgia. The great Muskhogean language family had no single name to distinguish as a unit the some fifty historic tribes.

As I have suggested on an earlier page, it is probably more correct to refer to prehistoric Muskhogean groups believed to have been resident in the Ohio Valley as proto-Muskhogeans.

Swanton advanced the theory that the social and ceremonial practices of the Creeks alone[9] were sufficient to have accounted for the great mounds of the Mississippi Valley and that the abandonment of the Ohio Valley mound area prior to white contact was evidently due to the shifting of Muskhogean tribes to the South or the movement of Siouan groups southeastward and to the west or both. Bushnell, in 1934, also postulated these movements.[10] Creek and Siouan traditions suggest the same. With physical and linguistic similarities as a suggestive basis future research may discover that the roots from which the Siouans developed grew in Muskhogean soil and that historical differentiation between the Creeks and some of the Siouans materialized after they left the Ohio Valley. Prehistoric contacts here were of great importance and, as yet, are but little understood. Archeological investigations show conclusively that two basic material culture patterns, Mississippi and Woodland, met in the Ohio Valley and manifestations of their intermixture are found in southern and central Indiana.[11] The peoples who produced these two patterns must have had historical cultural traditions of diverse origins. Archeology has a suggestion to offer concerning the bearers of the Mississippi Pattern. Material culture similarities in what is technically described as the Middle Mississippi Phase of the Mississippi Pattern are found in Arkansas and in southern Indiana from the lower Wabash River as far northeast as Clark County. This proposes the probability that among those who left these manifestations in Indiana were Choctaw-speaking Muskhogean Indians who in the shadowy period dividing prehistoric and protohistoric days found new homes in Georgia and Alabama, there to become historically known as members of the Muskhogean Creek confederacy.

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[9] Swanton, 1928, No. 2, p. 506.

[10] Bushnell, 1934.

[11] Lilly, 1937, pp. 22-24; Black, 1934, pp. 192-94.

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Ofo-Biloxi Sound Correspondences

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John R. Swanton, who rediscovered spoken Ofo in 1908, when it was thought to have been extinct since 1784, found that he was able to record Ofo with somewhat fewer [phonemic] symbols than Dorsey had previously used for recording Biloxi; notably differing from Biloxi is the Ofo *–Ch–* sequence. "Probably the consonants followed by *h*, which is here very distinct, correspond to the aspirated consonants of other Siouan dialects."[1]

On a close reading of the author's Bulletin 47, I find that he nowhere places the Ofo and Biloxi in a sub-group by themselves; indeed, in looking for the nearest relatives to these two languages, Swanton even mentions distant western kin of the Biloxi (p. 10), but for more intimate relationship the eastern Siouan tribes in general are indicated, which makes Biloxi and Ofo fall incidentally in one large eastern group rather than rest exclusively in a small southeastern group (p. 12). Later papers by the same authority ("New Light . . ." 1923, "Early History . . ." 1936) show more interest in the extreme divergency of Catawba than in placing Biloxi and Ofo more closely with themselves or with other Siouan dialects.

Two factors would naturally make one hesitate in ascribing Biloxi and Ofo to one genetically homogeneous group. A rapid survey of the two vocabularies shows that only a fraction of the words known are cognate—contrast this with the Hidatsa-Crow group, where a good sampling shows almost all words to be cognate. Secondly, the Ofo, alias Offagoula, alias Mosopelea, were supposed to be in the Ohio Valley in early times, going south to become neighbors of the Biloxi only after the 17th century.

As to the first factor, a large fraction of non-cognate words in Ofo and Biloxi suggests close, perhaps recent, cultural contacts with Muskogean speaking tribes; this can be demonstrated only after a large body of pan-Siouan and pan-Muskogean words are collected. As to the second factor, if comparative work can show Ofo-Biloxi to be a genetic sub-group of Siouan, historical evidence for early Siouan occupancy of the Ohio Valley will need to be interpreted as including both members of the group, with the Biloxi preceding the Ofo south rather than remaining in the south to be joined by the Ofo; comparative work for demonstrating a genetic sub-group must ultimately include all related languages, but a study limited to the two languages directly involved can provide a tentative hypothesis.

The correspondences which follow would seem to indicate that the Ofo and Biloxi at one time spoke a single language which changed in both Ofo and Biloxi, but rather more in the latter; that is to say, Ofo appears to be the more archaic language of this group.

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[1] 1. p. 4.

Examples are from the Dorsey-Swanton Bulletin 47; one example for each correspondence is cited, together with a parenthetic number indicating the total number of correspondences found. Only the more obvious cognates were counted by me.

1. *p* : *p*(15) and *ph* : *p*(12). Ofo *itce'pe*, Bil. *ayepi*, *aye'wi* 'door, window'; Ofo *aphe'ti*, *aphi'ti*, Bil. *pe'ti*, *peti'*, *pet* 'fire'.

2. *m* : *m*(8). In all examples except one, the Biloxi cognate lacks the initial vowel of the Ofo form; the remaining example reverses this relationship of initial vowel. Ofo *ama*^{n}*'*, Bil. *ma*, *mani* 'turkey'; Ofo *ma'hi*, Bil. *imahi*^{n}*'* 'to paddle'. Other laibials *(w, b)* may perhaps be regarded as phonetic variants of the phonemes *p*, *ph*, *m*. Swanton says (Bull. 47, p. 2), Bil. "*b* occurs only once, in a proper name." The phonemic status of Ofo *b* is doubtful. According to the printed orthography, Ofo *b* corresponds to Bil. *w* twice (as does Ofo *m* and *p*), to Bil. *p* once.

3. *t* : *t*(17), *d*(16) and *th* : *t*(9), *d*(1). Ofo *to'pa*, Bil. *topa'* 'four'; Ofo *te*, *ti*, Bil. *de* 'to go'; Ofo *the*, *txe*, Bil. *ti*, *tedi* (with medial *t*) 'to die'; Ofo *athi'*, Bil. *adi* 'father'. Ofo *t* and *th* also correspond to Bil. *n*(3), *tc*(2), *ts*(1), *xy*(1), *y*(1) possibly reflecting Biloxi phonology rather than regular correspondence (parallel to the development of Hidatsa *t* and *p* from *r* and *w* in final position, for example). The phonemic status of Ofo *d* is in question; correspondences with Bil. (3) are as for Ofo *t*.

4. *tc* : *tc*(12), *t*(3), *d*(2) and *tch* : *tc*(6), *t*(1). Ofo *iletci'*, *ile'tci*, Bil. *yetci'* 'tongue'; Ofo *itca(tho')pka*, Bil. *itapka* 'pestel'; Ofo *itco'ti*, Bil. *do'di* 'throat'; Ofo *tchi'pi*, Bil. *tciwi'*, *tci'wiya*^{n} 'intestines'; Ofo *itcho'hi*, Bil. *tohi*, *to'hü* 'green, unripe'.

5. *tc* : *y*(11). Ofo *tca'maki*, Bil. *yamaki'* 'mosquito'.

6. *k* : *k*(22) and *kh* : *k*(5). Ofo *atce'ki*, Bil. *yek*, *ye'ki*, *ayeki* 'corn'; Ofo *akhu*, *ku*, Bil. *ku* 'to give'.

7. *l* : *n*(4), *d*(2), *y*(cp. 'tongue,' under 4, above). Ofo *le'yi*, Bil. *niye* 'to fly'; Ofo *li'tchi*, Bil. *ditci'* 'to dance'.

8. *n* : *n*(20). Ofo *ano'*, Bil. *ana*^{n}*'* '(north), winter'. An instance is found of *n* : *t* (but cp. the reverse, 3, above). In two cases a nasalized vowel in Ofo implies a nasal consonant in Biloxi (but all records of Siouan dialects are a little ambiguous in distinguishing between nasalized vowels and vowels juxtaposed to nasal consonants).

9. *y* : *n*(2), *y*(cp. 'to fly', 7, above). Ofo *iya'ti*, Bil. *na(ha)ti'*, *na(ha')di*, *na(ha')ti* (with medial *t*, *d*, and fortis *t*, apparently free alternates) 'canoe'.

10. *f* : *s*(9) and *fh* : *s*(9). Ofo *atcu'fi*, Bil. *yusi*, *ayusi'* 'ashes'; Ofo *fhi*, Bil. *si* 'yellow'.

11. *s* : *s*(5) and *sh* or *c* : *x*(9). Ofo *ako*^{n}*'si*, Bil. *ka*^{n}*xi'* 'bee'; Ofo *amashu'-pka*, Bil. *maxo*^{n}*-tka'* 'palmetto'. Is Ofo *sh* phonemically distinct from *c*? Cp. Ofo *aco'co*, Bil. *xoxo'* 'to cough'.

12. *h* : *h*(25). Cp. above under 2, 'to paddle', under 4, 'green'.

13. *i* : *i* not nasalized in either dialect (60; see examples above); nasalized in Bil. but not in Ofo (8); in Ofo but not in Bil. (1); in both

dialects (5). Ofo *i'fha*, Bil. *iⁿsu, iⁿsu'di* ‘tooth’; Ofo *iⁿthe'*, Bil. *ite', te* ‘forehead’; Ofo *iⁿ'tu*, Bil. *iⁿti', indi', i'ndiyaⁿ* ‘egg’.

14. *i* : *e*(6). Ofo *oⁿ'yi*, Bil. *ane', anedi'* ‘louse’.

15. *i* : *a*(8). cp. ‘door, window’, 1, above.

16. *e* : *i*(7). Ofo *a'mife*, Bil. *misi'* ‘to sneeze’.

17. *e* : *e*(32). See examples above.

18. *a* : *a* not nasalized in either dialect (51; see examples above); nasalized in Ofo but not in Bil. (6; see ‘turkey’, 2, above, where a nasal consonant is found in the alternate form); nasalized in both dialects (5). Ofo *kifaⁿ'*, Bil. *ksaⁿ, ksa'ni* ‘five’.

19. *a* : *u*(3). Cp. ‘tooth’, 13, above.

20. *o* : *o* not nasalized in either dialect (13; see examples above). In general, when Ofo *o* is not nasalized, the Bil. correspondence is *o* (but cp. *o* : *aⁿ* in ‘(north), winter’, 8, above); and conversely, when Ofo *o* is nasalized, the Bil. correspondences are *a* or *u* rather than *o*.

21. *oⁿ* : *aⁿ* (8; cp. ‘bee’, 11, above),*a*(4). Ofo *moⁿhe, i'to moⁿ'he* ‘to whoop (like Indians in old times)’ possibly corresponding only to the Bil. forms in *m*–, if these are distinct from forms in *w*–, namely, *wahe, wahe'di* ‘to cry out (as from pain)’ and *mahedi'* ‘to halloo, whoop; to cry as the diving duck’.

22. *oⁿ* : *uⁿ*(3), *u*(3). Ofo *oⁿni, oni'*, Bil. *uⁿni'* ‘mother’; Ofo *okho'nki*, Bil. *okuki* ‘to fish’ (vowel-*n* is equated to nasalized vowel for practical intention; see 8, above).

23. *u* : *u* not nasalized in either dialect (8; see ‘ashes’, 10, above). In general, when both dialects show *u* nasalization is not recorded.

24. *u* : *o* (8; see ‘palmetto’, 11, above). When Ofo *u* corresponds to Bil. *o*, one or the other vowel is nasalized.

25. *u* : *i* (2; see ‘egg’, 13, above).

26. V– : zero–, and –V : –zero. Numerous instances show Ofo words beginning in *a*– and Bil. words, without initial vowel, beginning in consonants (e.g., ‘turkey’, ‘palmetto’, 2 and 11, above); with equal frequency, Ofo words in *i*– correspond to Bil. words in consonant without initial vowel (e.g., ‘tongue’, ‘green, unripe’, 4, above); also, Ofo words in final –*i* frequently correspond to Bil. words in final consonant, without final vowel: *aⁿfhe'pi*, Bil. *sep, aⁿse'p, aⁿsepi* ‘ax’. This example shows what is possibly true for all initial and final vocalic loss, namely that the Bil. word appears to lack corresponding vowels only in certain forms. An instance where an Ofo word lacks initial vowel recorded for Bil. is also found (see ‘to paddle’, 2, above).

Loss of original vowel between consonants, resulting in consonant clusters, is evident in both dialects; here again, however, vocalic loss in Bil. is general, in Ofo specialized.

27. CVC : CC(18), with Ofo V representing all vowels, most commonly *o*(5), *a*(5), *i*(4). Ofo *asho'pi* ‘to drink’, Bil. *oxpa'* ‘to devour, eat up, drink up’; Ofo *oⁿ'fana*, Bil. *aⁿsna', aⁿsuna'* ‘duck’; for V representing Ofo *i*, see ‘five’, 18, above.

28. CC : CVC(3). Ofo *phe*, Bil. *pehe', apehe* ‘to pound’; Ofo *a'she*, Bil. *xehe'* ‘to sit’. The cluster, consonant–*h*, already noted by Swanton as an Ofo peculiarity, may represent in origin a CV*h* sequence, with V lost in syncope; –C*h*– is then doubtless extended analogically.

29. CC : CC(22). Some instances where clusters (e.g., *–sk–*) are found in both dialects will reflect a Primitive Siouan cluster; other instances will reflect an old syncope when other dialects are brought into comparison with Biloxi and Ofo. And one may also expect that Bil. and Ofo preserve some vowels lost in other dialects; thus, CVC (sibilant–*e*–*p*) in both Bil. and Ofo ('ax', 26, above) corresponds to CC (–*θp*–) in Osage: (*mo*^{n}–*hi*^{n}–)–*θpe* 'ax'.

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Relationships Among Various Clark County Sites

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The Ohio River forms the entire southern boundary of the State of Indiana. The archeological importance of this fact rests upon the evidence that the Ohio has served for centuries as a major artery for the migration and diffusion of various aboriginal peoples.

Although it is known that important aboriginal sites or landmarks appear about the mouth of every considerable stream entering the Ohio within this region, two principal occupational foci seem to stand apart from the rest as of special importance. One of these embraces an impressive area about the mouth of the Wabash River; the other comprises several square miles about, or near, Ohio Falls. As our investigations have extended, it has become increasingly apparent that the ethnology of these two locations is distinctly inter-related and that with each area there are evidences of marked changes in cultural characteristics occasioned by a contact or association of diverse peoples. At both locations the influence of such association upon pottery form and decoration is quite apparent.

Concerning the Ohio Falls location, it should be understood that, except at this point, there are no falls or rapids in the entire course of the Ohio. This is in itself important, especially when it is understood that from the earliest aboriginal times navigation about the Falls of the Ohio was of necessity accomplished by means of portages, one upon each side of the stream, both of which were within the actual precincts successively occupied by various Indian peoples.[1] What effect this situation may have had upon a prolonged and peaceful occupation of this eminently strategic location and to what degree such occupation may have affected migrations by alien peoples provide important elements in a critical archeological study of the region.

Nowhere in Indiana, or perhaps anywhere upon the Ohio, was there a more advantageous location for aboriginal occupancy. There was a remarkably abundant supply of fish-food and of the numerous species of edible molluscae, which persist to this day. Below the "falls" a glacial lake some 15 miles long was the habitat of great colonies of waterfowl. There were perhaps 100 smaller lakes existent a century ago. The extensive "knobland" forests abounded in deer, elk, bear, and other wild game. Beyond this the river terraces were here quite elevated and level, and the rich sandy loam was exceptionally fertile.

The fact is that various aboriginal peoples have successively occupied this immediate region, their villages overspreading more actual acres, perhaps, than is true of any other situation upon the Ohio. How many tons of animal bones have been left here—including those of mammals, fish, and fowl—no one may conceive. Numerous acres, within which were the burials of hundreds of early peoples, have been washed into the Ohio during the past 100 years. During the extraordinary inundations of 1883-1884 local newspapers reported the complete destruction of these sites; yet during our recent excavation some 200 burials were encountered, and it is probable that many times this number still remain.

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[1] Gordon, Capt. Harry, 1916. Coll. Illinois Hist. Libr. **11**:294.

The geologic history of Ohio Falls is exceptionally complex, but it is indubitably an important or even paramount element in the local archeological picture. In order to evaluate this close relationship, one must remember, for example:

1. That the earliest occupants of the Ohio Falls sites were "lake dwellers" rather than simply the customary occupants of villages established upon stream terraces.

2. That during some phase or phases of the occupational sequence in this quarter the Ohio was in the process of establishing a new course, migrating meanwhile over an early lake-bed to its present location some three miles west of its earlier long-established channel.

3. That the present islands below the rapids were once integrated with the mainland and that upon them aboriginal peoples lived in villages not yet dissected from this mainland by stream piracy.

4. That for some centuries, or at least since the Ohio has occupied its present channel, periodic major inundations have wholly destroyed certain of the early villages in this area and that it was frequently necessary over a long period of time for the occupants of other sites to abandon their homes for brief or long periods.

During the building of the Louisville & Portland canal (*circa* 1830) aboriginal "fire hearths," skeletal remains, and artifacts were reported found at depths 20 to 30 feet below surface on the Kentucky side of the Ohio. No valid reason appears to discredit these reports. An examination of the artifacts recovered reveals that they pertain to the "Indian Knoll" culture-group, as described by Moore.[2] That the occupants of these sites later resorted to the higher terraces upon the Indiana shore one may assume, but this is not after all important. What is important is, as Dr. Butts has pointed out, that it is not probable that any of the spectacular changes in the Ohio mentioned must be referred to remote geological times.[3] It is certain, however, that these varied and often puzzling geologic involvements must be carefully weighed and considered in any competent analysis of the archeology of the region.

The general archeological sequence at Ohio Falls, as we now interpret it, is as follows:

1. A late or historic occupation during pioneer and pre-pioneer times by small transient groups, some of which may be identified as Shawnee and Delaware; probably, also, transitory occupations by the Cherokee at a somewhat earlier period. It is known that the Cherokee claimed the whole of Kentucky as their tribal habitat, and there are

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[2] Moore, Clarence B., 1916. Some aboriginal sites on Green River, Kentucky. Philadelphia Acad. Nat. Sci.

[3] Butts, Charles, 1918. Reverse of topographic map of Camp Taylor and vicinity. U. S. Geol. Surv.

sparse records of Cherokee camps about Ohio Falls. In respect to the Shawnee and Delaware occupations the evidence is substantial and is a matter of fully authenticated record. So much may not be said of the probable Cherokee occupation of which the accounts are meager and less substantial.

Although Borden assumed that burials at Ohio Falls were "within stone graves and usually in a sitting posture,"[4] and Webb and Funkhouser[5] (probably upon these grounds) assumed also that this was true, we did not encounter during two seasons of excavation a single stone grave. It is true, however, that two or three stone graves are observable on surface within the lawn of the James Newcomb home (Newcomb site). No others have been observed or reported at Ohio Falls.

2. An intensive occupation, not however prolonged, by an integrated body of Middle-Mississippi peoples who, as we believe, were somewhat earlier established at Wickliffe, Kentucky; at the mouth of the Wabash; in Vanderburgh County, Indiana; and in Floyd County, Indiana, a few miles below Ohio Falls. This is the same group, we assume, who established themselves more unitedly at the Prather-Koons-Willey sites in Utica Township, Clark County, some six or eight miles north from Ohio Falls. This concentration perhaps represents the easternmost outpost upon the Ohio of the group in question. These people built impressive mounds above the ruins of rectangular structures earlier destroyed by fire, buried their dead usually in an extended position, but sometimes with bodies flexed, beneath the village floor-level, or actually beneath the clay floors of their homes, used copper liberally and artistically, were adept in the fabrication of axes, celts, pipes, etc., of stone, and produced pottery of decorative character—this often including effigy forms.

It should be understood that at Ohio Falls every available acre has been cultivated for 150 years, that recurrent inundations have removed much of the surface soil so disturbed, that erosion has greatly altered the entire surface, that tons of boulders and other workshop material have been removed to facilitate cultivation or to be utilized for cement construction, and that for a great many years relic collectors have resorted to this area and have combed it consistently. It has been therefore impossible to determine the actual areal extent of this occupation or to estimate its importance.

3. An intensive occupation of relatively long duration by a numerous group of Middle-Mississippi peoples. In physical character and in their material culture, they are unlike Group 2; yet there are certain trait-similarities which suggest a contact between the two peoples. In this group the cranium is small and customarily occipitally flattened. Undeformed crania, so far as studied, are moderately dolichocephalic. This is opposed to Group 2, whose crania are relatively large, undeformed, and brachycephalic.

We have found within the midden deposits characteristic of this group no fragment of copper. The burials are customarily upon the right side and are rather acutely flexed. This flexation has been sometimes insured through the introduction of post-like slabs of limestone placed at knees, hips, feet, etc. As a burial practice, round or ovate boulders, always carefully chosen, were deposited in the graves. Red ocher and charcoal appear sparingly with most burials. Most unusual, we believe, is the characteristic use of pillow-like head-supports of native slate—these sometimes worked into roughly oval form but more often representing squared or rectangular quarry-slabs. The inclusion of funerary pottery is typical, and a specific form of pot has been used. This is of one-half gallon capacity, the body is ovoid and thin-walled, the rim is slightly flared, and the two handles are looped and rivetted. This funerary vessel is shell-tempered, as are practically all of the thousands of sherds recovered. It is plain or polished, as is most of the pottery in general. Perhaps one-fifth of the utilitarian vessels were cord-marked. The size range of these is from small and delicate forms to those of exceptional size. Truncate pans and straight-sided vessels are numerous, as are the "water bottle" forms. In vessels with handles both the loop and strap handle appears, but we have not observed the lugged form anywhere within this region.

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[4] Borden, Wm. W., 1874. Indiana Geol. Surv. 5:185-186.

[5] Webb, W. S. and Funkhouser, W. D, 1928. Ancient life in Kentucky. Kentucky Geol. Surv., p. 174.

Within the abundant midden deposits there were no grooved axes and no celts actually identifiable as such. Pestles with expanded bases were numerous, as were more or less crudely shaped mortars. Digging or agricultural tools were customarily of native slate and were quite often notched. Projectile points, knives, and drills were preponderately of the Wyandotte hornstone, so generally used by Ohio River peoples. The small flint scraper so typical of Wabash River sites does not appear at Ohio Falls or indeed anywhere in this region. While triangular points were perhaps most numerous, notched and stemmed types are almost equally so.

Even though "grave goods" are in this manifestation rare, crude bone drills, needles, etc., are sometimes present, as are tubular beads of bone, and discoidal beads of shell. Except in the decoration of elbow pipes, upon the bowls of which human effigy faces or heads appear, there is little attempt at decorative expression. Although pipes of stone or clay in elbow, ovoid, and conical forms are abundant and are included with burials, decoration seems confined to the elbow type.

4. An occupation of especial importance, involving an extensive area upon both sides of the Ohio, of a group whom Moore has described from the Indian Knoll site upon Green River, Kentucky, some 150 miles southwest of Ohio Falls.

The material culture of this group has been so well described by Moore that we shall attempt here only a few observations by way of comparison. It must be concluded that the concentration of these peoples at Ohio Falls was much more extensive and prolonged than that at Indian Knoll and that it comprised, in fact, a tribal center of this group. There is much reason to believe, also, that it was occupied much earlier.

In general, the cultural character of the two sites is identical. There are, however, suggestive differences. Among these are:

a. That while Moore found numerous objects of copper at Indian

Knoll, we found none whatsoever at Ohio Falls, either within the midden deposits attributable to these people or in those of Group 3 above them.

b. That while Moore reports that the flint implements of Indian Knoll were customarily of a "dark flint," which we suspect was derived from the prolific quarries of southern Indiana, it was observed at Ohio Falls that the group of Indian Knoll affinity had apparently no knowledge of this material, or in any event, used it insignificantly. It is because of this fact that we are inclined to believe that a certain chronological value attached to the use or disuse of this material by Indian peoples upon the Ohio.

In almost every respect the material culture displayed at Ohio Falls was superior to that of Indian Knoll. It was obviously slightly affected, if at all, by contact with other peoples. Neither at Ohio Falls or at Indian Knoll does it appear that pottery was made or tobacco used. At Ohio Falls, at least, it is apparent that the use of the bow-and-arrow, if it was used at all, was much less practiced than the use of the spear or lance.

Inasmuch as Hrdlicka has assumed upon the basis of cranial characteristics that the people of Indian Knoll were Algonquin, none of the crania collected at Ohio Falls have been studied. Although there are numerous points in Hrdlicka's analysis upon which one may not agree, we are inclined to be receptive in respect to a possible Algonquin affinity. Our reasons are based upon abundant similarities in culture-traits, however, and not upon the physical element.

5. A possible "pre-Indian Knoll" occupation characterized by extensive underlying, midden deposits usually displaying a sod-line "break" or contact between the inferior and superior midden accumulations. The homogeneous and richly organic deposits of this stratum are, in fact, quite different in character from those of the identified Indian Knoll levels. They are composed almost entirely of millions of small molluscae (Pleurocera, Campeloma, etc.) in varying stages of disintegration; this is opposed to midden deposits of the superior strata, in which the Unio prevails. There are within this stratum no bones of larger mammals, except such as may have accrued from the midden deposits above. Instead, the animal remains comprise those of fish and waterfowl. Though our excavations have revealed that this deposit extends to a maximum depth of 8 feet 9 inches, resting sometimes upon sterile glacial outwash clays and in other quarters upon the lacustrine clay of the earlier lake-bed, the whole of human origin, we have found nowhere human remains or artifacts within it.

It is admitted that we have heretofore assumed that this midden was attributable to an occupation by the group of Indian Knoll affinity, this assumption based upon the unreliability of "sod lines" in sites of this character and upon the fact that the Indian Knoll midden upon the Kentucky side was upon the same glacial clays, or marls, earlier mentioned.

Upon the now denuded islands below Ohio Falls and upon the low rock shelves slightly above the normal pool-stage of the Ohio, Folsomoid projectile points have been found frequently. Almost invariably these are patinated and reworked. Upon an extensive low terrace upon a branch of Silver Creek in Monroe and Union townships, similar Folsomoids have been found at several unimpressive campsites, these barren of pottery, so far as we have observed. It is of course possible that the Folsomoids of Ohio Falls may have derived from the stratum we have just described, for certainly none have appeared in the upper strata.

At the Robinson site in Washington Township, there is an impressive circular earthwork. Near this are a number of unexplored stone graves, these quite obviously representing an intrusive occupation of the site by later peoples. At the so-called "stone fort" at the mouth of Fourteen Mile Creek, a difficult examination of the surface has revealed no other evidence than a few plain or cordmarked, shell-tempered sherds and a customary use of Wyandotte flint. Artifacts from an apparently related village site suggest a Middle-Mississippi association. Upon the site itself triangular arrow points appear most numerous.

In the foregoing we have attempted to discuss as briefly as possible the several complications presented in the region. It must be admitted that the entire Ohio Falls region is decidedly important archeologically. It must appear obvious that our own survey has accomplished little more than to suggest the desirability of further investigation.

SECTION ON BACTERIOLOGY

Chairman: P. A. Tetrault, Purdue University

Good interest was maintained throughout the session of the section on Bacteriology. About 25 or 30 members were present during the greater part of the session. Since the program was short, no time limit was placed on discussion. The paper on *Streptococcus algalactiae* and that on immunization against rabies were discussed in considerable detail. A. R. Jamieson, of the Lilly Research Laboratories, was elected chairman of the section for the coming year.

ABSTRACTS

Disinfection. P. A. Tetrault, Purdue University.—A general review of the action of disinfectants from bacteriological and chemical standpoint is presented. The influence on the rate of disinfection of such factors as change in concentration, temperature, pH, chemical constitution of disinfectant, and presence of organic matter is outlined.

Immunization against rabies using vaccines containing various amounts of protein. C. A. Behrens, L. B. Schweiger, and J. L. Reeves, Purdue University.—All vaccines employed in prophylaxis against hydrophobia contain the virus of rabies and also a great deal of foreign material, practically all of them being suspensions of the infected nervous tissue of rabbits. Much of this undesirable foreign substance can be removed by precipitating it at its iso-electric point. These experiments employed vaccines with varying amounts up to about 60% of this inert material removed. The vaccines were prepared by adding homogeneous rabic brain emulsions to 0.2, 0.4, 0.5, 0.6, 0.8, 1.0, and 1.1 mls. of 1/100 molar citric acid, this procedure removing 15, 24, 30, 34, 43, 58, 62% of the protein. Their minimum lethal doses are 0.5 ml. injected intracranially of dilutions of 1 to 14000, 12000, 12000, 12000, 50000, 3000, and 2000, respectively. When 0.5 ml. of a rabic brain emulsion is similarly injected in rabbits, a dilution of 1:25000 is fatal; a dilution of 1:26000 is non-infective. Rabbits were immunized by injecting 2 or 10 mls. daily for 10 days and, consequently, received 20 or 100 mls. of these vaccines, subcutaneously or intravenously. Ten or 28 days after their last vaccine treatment they were tested to ascertain their degree of resistance by injecting intracranially 0.5 ml. of a 1:20000 dilution of rabic emulsion. All vaccinated rabbits, irrespective of the amount, the type, or the method of administration of the vaccine, were able to withstand two minimum lethal doses 10 or 28 days after receiving their last vaccination. Rabbits inoculated intravenously with 2 ml. doses, receiving 20 mls. of the vaccine, seemed to possess greater resistance against 3 minimum lethal doses than those injected subcutaneously when tested 28 days after their last vaccine treatment. Fifty per cent of the rabbits injected daily subcutaneously or intravenously with 10 ml. doses, receiving 100 mls. of the vaccine and tested against

3 minimum lethal doses 10 or 28 days after vaccination, are immune to rabies. None of the immunized rabbits withstood 4 minimum lethal doses.

Factors influencing the growth of *Oospora lactis* in cream. E. H. PARFITT, Purdue University.—When cream is held under farm conditions, the factors influencing the growth of *Oospora lactis* are found to be the time and temperature, the amount of cream surface area exposed to the air, the degree of agitation of cream during storage, the method of adding fresh cream to the accumulated supply, and the milk-fat content of the cream. Molds in cream are of interest in that a knowledge of their population may be used as an index of the state of decomposition of the cream.

Biophysical study of *Oospora lactis*. E. H. PARFITT, Purdue University.—From sour cream and butter were isolated what appear to be eight different varieties of *Oospora lactis*, which were found to differ in macroscopic and microscopic appearance, ability to hydrolyse milk fat, production of spores and mycelia when grown in substrates of different pH levels, ability to produce an odor, thermal death points, and optimum growth temperatures.

The detection of chlorine-resistant bacteria in a swimming pool. G. H. ECHELBARGER, Purdue University.—This paper reports the number of organisms present in a chlorinated swimming pool and the effect of certain physical and chemical factors upon holding samples.

The application of the phosphatase test to butter. W. H. BROWN, Purdue University.—The phosphatase test as it is used for milk has been applied to butter to determine whether or not the cream has been properly pasteurized prior to churning. The Scharer technique has been followed, with 1 ml. of butter serum used to replace the 1 ml. of milk. The butter serum is collected by centrifuging the sample of melted butter. The test shows that some samples of the commercial butter react phosphatase-positive. A large percentage of the samples that gave a positive phosphatase test, when subjected to the keeping-quality test of 15.4° C. for 10 days, dropped in score more than did those that gave a negative phosphatase test. The method used to pasteurize the cream has been found to influence the number of samples reacting to the test, and the test points out that pasteurization is an individual plant problem.

Milking machines a source of thermoduric bacteria. E. H. PARFITT, Purdue University.—In one of the large middle western cities where difficulty was found in maintaining a satisfactory bacterial count in adequately pasteurized milk, investigation showed that the incoming milk from certain territories was heavily inoculated with thermoduric bacteria, and these thermoduric bacteria were associated with insufficient care of milking machines. The organism isolated was a gram-positive micrococcus, which, when growing on nutrient agar, produced in from four to six days a yellow pigment, did not reduce methylene blue or litmus, and had a majority thermal death point between 65 and 67° C. when held for 30 minutes of time.

The Rapid Identification of *Streptococcus agalactiae*

Alfred H. Brueckner and Stanley E. Hartsell, Purdue University

The typing of streptococci by serological methods, particularly the precipitin technique of Lancefield (1928) has been shown to be reliable not only for the identification of cultures but also for the demonstration of the various antigenic constituents of their cells. To those interested in the rapid detection of streptococci the problem of making this technique available to dairy and health laboratories is receiving considerable attention at this time.

It is obvious that such a method would be of great assistance to these institutions; however, one feature of precipitin techniques is that the preparation of large numbers of extractives from the cultures and the necessary centrifugation of the cells is time-consuming. These factors may be a limitation in some laboratories doing routine bacteriological work with milk, and any test which could obviate these difficulties would be greatly appreciated.

It appears that a rapid, inexpensive, and reliable method for the determination of Group B streptococci by the agglutination method could be used to good advantage in reducing the number of cultures which would require the precipitin technique before their group would be known. However, we observe frequently that any attempt to utilize agglutination methods with cultures of streptococci has had little success because of the tendency of these forms to agglutinate spontaneously. Griffith (1926) devised a method with which he could classify *Streptococcus pyogenes* by the use of a rapid slide agglutination test. Later Stableforth (1932) utilized a similar technique for the identification of *Streptococcus agalactiae.* In a recent report Stableforth (1938) records the extensive use of this test in typing many strains of this microörganism. Even the identification of sub-types within Group B streptococci was accomplished with relative ease. Some cultures were spontaneously agglutinable or inagglutinable, and further tests were required before their serological type could be known. Plastridge and Hartsell (1937), in their work on the biochemical and serological reaction of *Streptococcus agalactiae,* discarded this method because of these difficulties.

The present report describes the development of a microscopic slide agglutination technique for the rapid detection of *Streptococcus agalactiae* after its isolation from routine milk samples. Spontaneous agglutination among cultures has been greatly reduced, and by the use of this test *Streptococcus agalactiae* can be identified in 72 hours after the milk sample has been taken. No biochemical or involved serological tests are required to type most of the strains of this organism. An attempt to adapt the Neufeld technique to the identification of *Streptococcus agalactiae* will also be discussed.

Preliminary Experiments

In studying the biochemical and serological relationship of *Streptococcus agalactiae* (1937), the encapsulation of some cultures was noted on primary isolation. Stained smears made from the incubated milk tubes showed well marked capsules; however, these structures were seen so infrequently that they were regarded as artifacts. It seemed appropriate to reinvestigate this problem with a view to adapting the Neufeld technique for the typing of pneumococci to the identification of *Streptococcus agalactiae.* Such an adaption, if successful, would obviate the necessity of using blood agar plates and subsequent biochemical and serological determinations of the pure culture for the detection of this species in milk.

Cultures.—Twenty-four cultures of streptococci, regarded as members of Lancefield's Group B, were received from Dr. W. N. Plastridge. These strains included the well known cultures "090 T" and "V9" of Lancefield, as well as strain PH 281, which was isolated originally by Mr. Mickle. The first two of these strains have been studied extensively by many investigators, the most recent report concerning their encapsulation being that of Dawson (1938).

Antibacterial serums.—Antiserums were prepared by injecting rabbits intravenously with a 0.5% suspension of packed formalized cells in saline solution. These antigens contained the growth from cultures cultivated in a proteose-peptone, phosphate beef-infusion medium for 48 hours. The rabbits were injected according to the method of Foote, Welch, West, and Borman (1936), which had been shown to be suitable for the production of satisfactory Group B antiserum (1937).

Capsule stimulation.—Since most of the pure cultures did not show a well-defined capsule, the first problem was that of inducing the development of this structure before the Neufeld technique could be applied. Daily transfers of the 24 strains were carried out in a blood-milk broth with a beef-infusion base. Examinations for capsules by the method of Howie and Kirkpatrick (1934) after three transfers showed slight capsule formation in 13 of the 24 strains. It was observed that capsular development under these conditions was variable and that large capsules were never found.

Negative results were also obtained by using blood-milk agar slants (5% cow blood, 5% milk in beef infusion agar) and a skimmed milk medium even when daily transfers were continued for ten days. Passage of the cultures through mice failed to stimulate a definite increase in capsular material. In the presence of homologous serum, 090 T and all other strains failed to show capsule swelling.

In view of the work of Jennings (1931) with human streptococci, the methods of bacterial variation were employed to encourage capsule formation. He showed that unencapsulated streptococci might become capsulated and grow as mucoid colonies on blood agar after many transfers in blood media. Dawson (1938) has recently reviewed the literature on this subject and records the development of the mucoid phase and capsules for strain 090 T.

It was thought that an encapsulated strain of *Streptococcus agalactiae* (possibly strain 090 T) might be used with the serum of cows to detect mastitis. Then it would be possible to eliminate the use of any cultural methods for the detection of infection due to this species. The presence of antibodies in the serum of the infected cow would constitute a positive diagnosis. With this viewpoint in mind strains 090 T, V9, and PH 281 were grown in blood broth and transferred daily for six days. On the seventh day blood agar plates were streaked and then incubated for 24 hours at 37° C. A small inoculum from the edge of the colony was transferred again to blood broth. This procedure was carried through six series without a mucoid phase being observed in any of the plates. This part of the work is being extended.

Observation of capsule swelling.—Whenever even slightly encapsulated organisms were noted in the above experiments, they were subjected to exposure to homologous serum in a hanging drop and observed for capsule swelling. The first hanging drops were examined immediately as in the Neufeld technic. Then incubation of the serum-antigen mixtures was tried at 37° C. for one hour. Even when these preparations were held at this temperature for 24 hours in a humid atmosphere (water bath), no capsule swelling was seen. In these experiments we noted that many of the serums caused a consistent and definite agglutination of their antigen; and in view of the many unsuccessful attempts to produce the swelling, a further study of this agglutination was considered expedient.

The Microscopic Agglutination Test

The same serums used in the work just reported were employed in a reinvestigation of the microscopic agglutination test. It was first demonstrated that serums for strains 090 T, V9, and PH 281 had a precipitin titre of 1-100 and that only a slight reaction was observed in cross-precipitin tests. The precipitation with the homologous serum was sufficiently strong so that there was no question as to type relationships. Cross-agglutination tests also supported these correlations. In the identification of *Streptococcus agalactiae* on primary isolation the three antiserums for Lancefield's types I (Strain 090 T), II (Strain V9), and III (Strain PH 281) were employed.

Strains to be used as antigens were grown in beef-infusion proteose-peptone broth containing approximately 5% defibrinated cow blood. One loopful of the broth culture which had been incubated at 37° C. for 12-18 hours was removed from the upper half of the medium and placed on a clean cover slip. Every effort was made to keep from agitating the culture, since very few calls were needed in the hanging drop; and large granular clumps of cells which occur frequently on the sides of the tube would confuse the detection of agglutination. One loopful of undiluted antiserum was then added to the drop of culture. The addition of enough alkaline methylene blue to this mixture to color it lightly facilitates reading the tests but does not alter the reaction. The coverslip was mounted in the usual way and the preparation incubated over water at 45-50° C. in a water bath. Readings were made by microscopic examination of the hanging drop with the high dry lens. Final readings were made after four hours' incubation, although most positive tests were detected in two hours. A control, containing only a loopful of the broth culture, was made for each organism so that spontaneous clumping, if it occurred, would be detected. Positive tests showed definite clumping of the organisms as contrasted to the free chains of cells in the control. An arbitrary system of recording the extent of agglutination was adopted: 3+, approximately 90% of the cells in the hanging drop were in aggregates; 2+, about 50% were in clumps; 1+, from 10 to 20% of the cells showed agglutination. Occasionally, clumping reached a macroscopic state (4+) in strongly positive tests, and the clumps could be seen in the drop with the unaided eye.

Experimental

If the microscopic agglutination test is to be of any value in the routine examination of milk samples, it should require a minimum of time and materials and still give reliable results. With this viewpoint in mind, 261 quarter-samples of 59 cows were taken in two different herds and the 75 isolations of streptococci examined by the above technique.

Procedure with isolated strains.—The method of Plastridge and his associates (1934) was used in collecting the milk samples aseptically. They were incubated over night at 37° C. and then examined culturally. One loopful of each incubated sample was streaked on one quarter of a cow-blood agar plate and then incubated for 24 hours at 37° C. Breed smears were also made and examined for the presence of streptococci and for leucocytes in the incubated milk. All weakly hemolytic colonies were picked from the plates and transferred to beef infusion blood broth. In a few cases short chain streptococci were seen in the microscopic examination, but no hemolytic colonies were found on the original or repeated platings. These cultures proved to be micrococci or streptococci, giving biochemical reactions typical of *Streptococcus lactis.* All isolations in the present investigation which gave typical *Streptococcus agalactiae* biochemical reactions were weakly hemolytic. The broth cultures obtained from the blood agar plate colonies were used as antigens in the microscopic agglutination test. Each isolation was tested with antiserums prepared against organisms representing the three types of Lancefield's Group B Streptococci. Biochemical studies of all isolations were made according to the method of Plastridge (1934).

Results

Preliminary isolation experiments were done with a local dairy herd which was at that time having trouble with mastitis. Encouraging results were obtained with the microscopic slide agglutination tests, and a more comprehensive survey of a larger herd was undertaken to determine the efficiency of the test. Table I shows the biochemical and serological reactions of certain isolated strains.

TABLE I.—Identification of Selected Isolated Strains of Streptococcus agalactiae

Culture Cow Number	Source Quarter	Biochemical Reactions									Microscopic Slide Test Type Serums			Control
		Hemolysis	L.M.	M.B.	L.	Mn.	I.	Raf.	Sal.	Ar.	I (090 T)	II (V9)	III (PH 281)	
302	L.F.	beta	ACpR	0	A	0	0	0	A	0	0	2+	3+	—
295	R.R.	beta	ACpR	0	A	0	0	0	A	0	3+	3+	2+	—
299	L.R.	beta	ACpR	0	A	0	0	0	Sl.A	0	2+	2+	3+	—
290	L.F.	beta	ACpR	0	A	0	0	0	A	0	2+	2+	+	±
521	L.R.	beta	ACpR	0	A	0	0	0	A	0	+	3+	3+	—
306	L.F.	beta	ACpR	0	A	0	0	0	A	0	3+	3+	3+	—

Abbreviations: L.F. = left front quarter; L.R. = left rear quarter; R.R. = right rear quarter.
Biochemical Reactions: in Litmus milk, ACpR = acid, coagulation and partial reduction. L. = Lactose; Mn. = Mannite; I = Inulin; Raf. = Raffinose; Sal. = salicin; Ar. = Arabinose.
Reactions in Methylene Blue Milk: 0 = no reduction.
Fermentation Reactions: A = acid; 0 = no acid.
Serological Reactions: 0 = no agglutination; + = approximately 20% of cells agglutinated; 2+ = approximately 50% of cells agglutinated; 3+ = approximately 90% of cells agglutinated.

It will be noted that there is a remarkable agreement between the biochemical and serological properties of these strains. Seventy of the 75 isolations made in the present investigation gave cultural and biochemical tests which identified them definitely as *Streptococcus agalactiae*. As stated previously, only the reactions of representative isolations were included in the table. The other five strains gave reactions which were atypical of *Streptococcus agalactiae*, notably the complete reduction of methylene blue and litmus milk. These five cultures gave negative serological reactions, except for one, which gave a slight reaction with 090 T antiserum.

Of the 70 strains classified as *Streptococcus agalactiae*, 69 or 98.5% were detectable by the microscopic agglutination test, the one exceptional strain being spontaneously agglutinable to the point where clear-cut readings could not be made. Forty-four of the 70 *Streptococcus agalactiae* strains were isolated from different quarters, and 26 were obtained in repeat tests on the same quarters. Since the strains isolated on the second sampling of a given quarter often gave strong evidence of being the same as those isolated in the original sampling, especially in the intensity of the agglutination reaction; it is of interest to survey the data from this standpoint. In Table II we note that practically all strains, when isolated from the first milk sample of a quarter, can be designated easily as *Streptococcus agalactiae*. Only one of the 44 strains could not be typed. This indicated definitely that the test was

TABLE II.—Degree of Reaction of Isolated Strains Against All the Test Serums

Degree of Reactions*	Original and Repeat Isolations		Original Isolations Only	
	No. of Strains	% of Total Strains	No. of Strains	% of Total Strains
Strongly Positive	37	52.9	29	65.9
Positive	24	34.3	13	29.5
Weakly Positive	8	11.4	1	2.3
Spontaneous	1	1.4	1	2.3
Total	70	100.0	44	100.0

*The arbitrary standards for degree of reaction:

Strongly Positive = 3+ or 4+ reaction with at least one of the three test sera.

Positive = 2+ reaction with at least one serum and some reaction with two sera.

Weakly Positive = 1+ reaction only with any serum.

Spontaneous = cells agglutinated even in absence of any sera.

of value when a rapid determination for Group B streptococci was desired.

The question arises as to whether the three test serums employed in our investigation need be used when testing routinely for *Streptococcus agalactiae* or Group B streptococci in general. In this connection it should be remembered that, while the serums were not wholly type specific, they reacted much more strongly toward homologous than toward heterologous organisms. A survey of the weak and negative reactions of the 44 strains of *Streptococcus agalactiae* isolated from different quarters (Table III) shows that in our work it was advisable to use the three test sera.

Stableforth (1938) has shown that there is rather a close correlation between the infecting types of *Streptococcus agalactiae* in the different quarters of a cow and the prevalence of these types in the herd. The spread of the organism from one quarter to another quarter in the same cow has been shown by agglutination methods to be brought about by the

TABLE III.—The Number of Strains Giving Negative or Weak Reactions with Each Test Serum

Antiserum Prepared Against Strain:	Negative No.	Strains %	*± and + strains		Total % —and Weak
			No.	%	
090 T	2	4.6	8	18.6	23.2
V 9	1	2.3	4	9.3	11.6
PH 281	2	4.6	7	16.3	20.9

*4 strains weak with both 090 T and PH 281; 1 strain weak with both 090 T and V9.

same serological types. Some evidence to support Stableforth's observation was noted in the use of the microscopic agglutination test. Because of cross reactions found in the preliminary titrations, little was expected in the way of typing organisms. However, it was soon obvious that the isolated strains did show differences in their reactions toward the three sera, and typing of a sort was taking place.

The strains of *Streptococcus agalactiae* from the different quarters of 7 of 13 cows gave identical agglutination reactions. Five of the 13 cattle were re-tested a second time, and the data indicated that the infecting types did not change during the interval (three months) between tests. It is realized that the above data are too few to support all the facts on the spread of mastitis infection; however, the possibilities of the microscopic agglutination test in such a study is indicated clearly.

Agglutination tests were also made with all sera against the following species of streptococci: *Streptococcus lactis* (5 strains), *Streptococcus bovis* (4 strains), *Streptococcus citrovorus* (1 strain), *Streptococcus scarlatinae* (1 strain), *Streptococcus epidemicus* (1 strain), *Streptococcus fecalis* (2 strains). We are indebted to J. M. Sherman, Alice Evans, and B. W. Hammer for subcultures of these species. One strain of *Streptococcus bovis* (No. 113) gave a slight reaction in the presence of V9 antiserum. Three strains of *Streptococcus lactis* and one strain of *Streptococcus fecalis* reacted spontaneously; otherwise, all other agglutination tests were negative.

Discussion

From our results it is evident that the microscopic agglutination test can be used successfully in the identification of *Streptococcus agalactiae*. The difficulties of spontaneous agglutination have been to a large extent minimized by the use of young serum-broth cultures as antigens. Apparently, the serum present in the blood broth sensitizes the cells to the action of the agglutinins, thus reducing the probability of agglutination due to the electrolyte in the absence of specific antiserum. Since cow blood was used in preparing the broth media in this investigation, the possible influence of antibodies in the blood from a mastitis-infected cow was considered. We used the blood from cows shedding *Streptococcus agalactiae* and from other animals which were free from this infection. No difference was discernable in intensity of the agglutination reaction or in the type specificity of the streptococci when blood from these sources was employed in the preparation of media.

The use of a small amount of the broth culture, which is free from clumps of cells often observed in cultures of streptococci, may also minimize the probability of spontaneous agglutination. The necessity of resuspending the cells in a solution containing an electrolyte has been obviated and may account, in part, for the detection of 98% of the cultures without this limitation. The centrifugation of broth cultures has been eliminated in the slide agglutination test. Concentrated cell suspensions are not only unnecessary but even detrimental in the microscopic agglutination test.

It is of interest to compare the microscopic agglutination test and the rapid macroscopic agglutination test of Stableforth (1932). In the latter method "suspected colonies are picked into 30 cc. of serum broth, each streptococcal growth is centrifuged, and the deposit taken up in 0.5-1.0 cc. cabol-saline. A slide agglutination test occupying one minute is then made with the five sera, representing most of the British strains. A definite reaction with any of these is indicative of the particular type. If the result is negative, cultures are prepared in 100 cc. of glucose broth, extracted, and tested by the contact method with a group serum known to be specific for *Streptococcus agalactiae* or Streptococcus Group B."

In Stableforth's test the difficulty of spontaneous agglutination has not been satisfactorily overcome, since it is this phenomenon which limits observations to a one-minute period. In this one-minute observation time weakly agglutinable strains are evidently missed, and a retest is necessary. In the microscopic agglutination tests the suspensions are stable, with very few exceptions; and weakly agglutinable strains can be appropriately identified. The incubation period is longer, obviously; but confirmatory or repeat tests are unnecessary. This accounts for much of the reduction in time when typing large numbers of strains.

The quantity of medium required in the test is another consideration which should be recalled. The rapid macroscopic agglutination test and the precipitin test of Lancefield require a minimum of 30 cc. of medium. As little as 1 cc. of blood-broth culture will provide sufficient antigen for the microscopic agglutination tests.

Cross tests with streptococci belonging to groups other than Group B have shown the specificity of the test, and biochemical confirmation with all isolated strains has served to prove its sensitivity.

It is possible that the test described here, in addition to its practical applications, might have taxonomical uses if different immunological methods were utilized and absorbed sera employed in the test. According to Lancefield (1934), specific type antibodies must be made by several series of injections with the group specific antibodies giving way to the type specific antibodies as the injections progress. Stableforth in his agglutination test for types used absorbed serums. However, in the detection of *Streptococcus agalactiae* as a species, serums of high group titre are preferable for the identification of all Group B strains isolated. Though a knowledge of the various subtypes of Group B is of significance to those interested in the epidemiology of mastitis infection, the classification of an isolated strain as a Group B microörganism would probably be sufficient from the standpoint of dairy and health laboratories. The practicability of the microscopic agglutination test in this regard is evident.

Conclusions

An attempt to adapt Neufeld's capsule swelling to Group B streptococci failed for lack of a method of rapidly inducing consistent capsule formation in the species tested.

A rapid microscopic agglutination test for Group B streptococci is presented. The test has shown close correlation with biochemical tests for the identification of *Streptococcus agalactiae.*

The test was successful in identifying 98% of the freshly isolated strains of this microörganism. This efficiency is attributed to the methods employed in obviating the difficulties of spontaneous agglutination which are inherent in cultures of streptococci.

There is a suggestion that data assembled by the use of the microscopic agglutination test is in accordance with the conclusions of Stableforth in his work on the etiology of mastitis.

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SECTION ON BOTANY

Chairman: Floyd E. Beghtel, Evansville College

The papers published below, in full or in abstract form, were presented in the sectional program. Dr. Winona H. Welch, of DePauw University, was elected chairman of the section for 1939.

ABSTRACTS

A comparison of market milk from ten Indianapolis companies by use of the direct microscopic method of analysis. Ina Stanley, Butler University.—One quart bottle of milk, delivered by each of ten companies to homes, was used for this analysis. This was done in July, 1937, and repeated in September, 1937. Both plate and direct microscopic methods were used. Plate counts for July ranged from 4,000 to 120,000; for September from 1,000 to 198,000. Six companies showed increase in September over July and four showed decrease. Direct counts for July ranged from 8,100,000 to 31,910,000 and in September 2,840,000 to 20,930,000. From the direct counts all companies showed decrease in September as compared with July. Staphylococci were the most abundant form of organism in three companies for both July and September and in two additional companies for September. In all other cases diplococci were the most abundant type. Tables are presented showing number of staphylococci, diplococci, long streptococci, short streptococci, body cells, and fungi for each sample of milk studied. Significance of large numbers of each type of organism in terms of milk production and handling is discussed. The general conclusion is reached that in all cases quicker and better cooling methods are desirable and higher standards of cleanliness are necessary in the case of apparatus, especially in that used before the milk reaches the dairy.

A fossil pollen study of Kokomo Bog, Howard County, Indiana. John W. Howell and Ray C. Friesner, Butler University.—The lower eleven feet of deposits show that a typical Canadian type of coniferous forest, dominated by Abies and Picea, was the pioneer after the soil was left by the glaciers. Pinus is the only other genus represented in the lower seven feet of deposits, but Larix is present in the deposits eight feet from the bottom. Twelve feet from the bottom, Abies and Picea lose dominance in favor of Quercus and Betula. Fifteen feet from the bottom, Betula begins to lose out, and Quercus retains undisputed dominance to the surface, never being approached by any other species. Abies and Picea drop out entirely a few feet after their dominance is lost, but Pinus remains in low frequencies to the first foot below the surface. Larix continues until within 12 feet of the surface and then disappears entirely. Broad-leaved trees in addition to those above mentioned were Acer, with a maximum of 10% in 10-foot level; Carya, 25% maximum at the 8-foot level; Fagus, 5% maximum in the 2-, 4-, and 11-foot levels; Juglans, 12% maximum at the 1-foot level; Populus, 13% maximum in the 2-foot level; Salix, 9% maximum in the 19-foot level; Tilia, 5% maximum in the 10-foot level; and Ulmus, 16% maximum in the 16-foot level. The following forest succession is shown: Abies-Picea, Abies-Picea-Larix, Quercus-Betula, Quercus-Carya, Quercus-Betula, Quercus-Juglans-Carya. (Butler Univ. Bot. Stud. 4:117-127. 1938.)

Prominent European botanists and herbaria. WINONA H. WELCH, DePauw University.—A brief story of a study of some European herbaria, with slides showing well-known botanists and herbaria.

Forest succession in the southern limits of early Wisconsin glaciation as indicated by a pollen spectrum from Bacon's Swamp. JAMES H. OTTO, Butler University. — Forest succession in the Bacon's Swamp region since Pleistocene times was determined by analysis of fossil pollen preserved in peat and marl deposits in the bog. Bacon's Swamp is a significant station because of its location near the southern limits of early Wisconsin glaciation. Samples from two borings, one 32, the other 22 feet in depth, were examined. Forest succession was from Abies-Picea while early deposition was in progress, to mesophytic Acer-Fagus-Quercus forest of the present day. Climatic periods indicated are cool moist, moderately dry, warm with increased dryness, and warm moist. Results from the two borings correlated well. Results were similar to those from other bogs of early Wisconsin depositions. (Butler Univ. Bot. Stud. 4:93-115. 1938.)

Additional records for some of the less common algae. C. MERVIN PALMER, Butler University.—New localities are here reported for several American algae. Included are several forms not frequently encountered, such as Desmonema and Hydrurus from California, and Nostochopsis, Nodularia, Colacium, Stichococcus, Chlorotylium, Compsopogon, Mischococcus, and Mesotaenium from Indiana.

Notes on an early and little known Indiana botanical journal. LAWRENCE J. KING, Earlham College.—A search into the literature of Wayne County botany has revealed an almost unknown publication containing a number of papers on the flora of Indiana. This journal, the *L. B. Case Botanical Index*, was first published in Richmond, Indiana, in April, 1877, shortly after the establishment of the *Botanical Gazette* by John M. Coulter at Hanover in November, 1875. It was published quarterly for about four years. The early issues were scarcely more than trade catalogs, but, with the withdrawal of Mr. Case from business in 1880, the journal became more truly scientific. It was illustrated profusely with woodcuts. The circulation reached 5,000. The publication was suspended with the March, 1881, number (Vol. 4, No. 2). Lucien B. Case, the editor and publisher, was a prominent florist at that time and was active in scientific circles in his own community and the state as well. He was the corresponding secretary of the Richmond Scientific Association for several years, and he also served as the first secretary of the Indiana Archaeological Association. While the journal was largely horticultural in nature in the early issues, many items of a more strictly botanical character were included in the later numbers. Of the articles published, two by W. C. Steele are of particular importance: "The Orchidaceae of Northern Indiana," and "A Brief Note on the Ferns of the Vicinity of La Porte, Indiana." Mrs. M. P. Haines' list of "Musci, Hepaticae, and Filices in the Vicinity of Richmond, Indiana," republished later in a modified form in the Indiana Geological Report in 1879, was also included here. Two articles on the "Big Trees of Indiana," one by B. W. Smith and the other by an anonymous writer, conclude the list of the more important contributions published in the *Index*.

Microclimate, evaporation, and epiphytic mosses. J. E. POTZGER, Butler University.—A comparison is made of trees on the Butler University campus and a typical beech-maple woods on the Fort Harrison reservation. Atmometers were placed at the bases and at a height of six feet on the north and south sides of trunks of trees in upland environment and in shallow ravines. For a period of 16 weeks the south sides had greater evaporation than the north, and higher parts of the trunks greater than the bases. Trees growing on ridges on the Butler campus showed greater evaporation than those similarly located at Fort Harrison. Local environmental influences frequently obliterated the effects of exposure and topography. (Bryologist, 1939.)

A quantitative study of the phytoplankton of Lake Michigan collected in the vicinity of Evanston, Illinois. WILLIAM ALLEN DAILY, Butler University.—A weekly quantitative study of the phytoplankton of Lake Michigan at Evanston, Illinois, was made over a period of one year, May, 1937, to May, 1938. Several ecological factors were studied in conjunction with the seasonal periodicity of the phytoplankton, e. g., temperature, turbidity, hydrogen-ion concentration, bacteria, and sunlight. The Sedgwick-Rafter method was used in the study. Forty-three genera representing five classes were recorded. In order of numerical abundance, the classes were Bacillariophyceae, Chrysophyceae, Myxophyceae, Chlorophyceae, and Dinophyceae. There was a considerable weekly variation and a marked seasonal periodicity in the total phytoplankton and in its variety. Strong maxima were noted in June and October. The diatoms dominated the phytoplankton at all times, both in total number and in number of species. (Butler Univ. Bot. Stud. 4:65-83. 1938.)

A test-tube spiral absorption vessel. RAYMOND E. GIRTON, Purdue University.—An efficient and compact carbon-dioxide absorption vessel has been designed for experiments in plant respiration. A test tube and a two-holed rubber stopper enclose the system. A vertical inlet tube carries the air stream to the bottom of the test tube where it is released in the form of small bubbles. These are caught and travel upward through the absorbent solution, in a submerged spiral glass tube. A short outlet tube carries the air stream out of the vessel after the spiral has been traversed.

A pollen profile of Otterbein Bog, Warren County, Indiana. RUTH R. RICHARDS, Butler University.—The bog was filled in forty-four feet, of which twelve feet were marl. Pollen in the lower nine feet indicates an Abies-Picea-Pinus dominance. Picea and Pinus persisted in small percentages to the surface, while Abies disappeared at the 15-foot level. Salix had a higher percentage of pollen at the 34-foot level than any other genus, while the three conifers here showed a sharp decline. Quercus was the most important genus from the 32-foot level to the surface. Acer was most prominent at the 13- and 18-foot levels. The top levels indicate a Quercus-Carya climax with an Ulmus subclimax.

Notes on Indiana grasses. J. E. POTZGER, Butler University, and CHARLES M. EK, Kokomo.—A list of grasses from counties from which they have not previously been reported.

A modification of the Osterhout apparatus for the measurement of plant respiration. CLINTON H. HOBBS, Purdue University.—The Osterhout apparatus, as originally designed, did not give results within a range of 5% when used in measuring plant respiration. A modification of the apparatus involves a colorimetric determination of the production of carbon dioxide by a photoelectrical method. Data are presented which show the greater accuracy of the modified apparatus.

The malachite-green differential culture-test as applied to sex-reaction strains of *Nectria coccinea*. M. L. LOHMAN and WILMA E. BURMAN, Indiana University.—Sexual reaction strains of a fungus diagnosed as *Nectria coccinea* (Pers.) Fr. (in the sense of Wollenweber) were grown on a special nutrient agar medium containing malachite green in concentrations ranging from 0.125 to 1.0 p.p.m., to determine the relationship of physiological culture types to known dye-toxicity values for the fungus. Colony diameters of plate cultures, with and without the dye, were recorded on the 10th and 15th days. Nearly identical toxicity values were found for all cultures of both strains when growth was inhibited by moderately to strongly toxic concentrations of the dye. The calculations indicate that, for the culture conditions maintained, a concentration of 0.00022% dye would be required to reduce growth to 25% of that on the control medium. However, inhibition values for the weaker concentrations studied showed a wide range since the cultures were either stimulated or inhibited in growth in varying degrees. With these concentrations some tendency to a differential response by strains was evident.

The anatomy of the leaf of *Streptochaeta spicata*, a tropical grass. PAUL WEATHERWAX, Indiana University.—The mature leaf of *Streptochaeta spicata* has in the mesophyll a series of air spaces apparently unlike any which have thus far been reported. These are formed from a special layer of parenchyma cells which thicken their walls and collapse as they die, forming a number of structures similar to steel I-beams.

Leaf-spot of Black Cherry

Robert E. Wean, Purdue University

In order to determine if initial penetration of leaf tissue on *Prunus serotina* Ehrh. occurred through the upper or lower leaf-surface, a conidial spore suspension (the Cylindrosporium stage) was secured by scraping spores from diseased leaves. The solution was then applied by means of a camel's hair brush to the upper epidermis of fifteen healthy leaves and to the under surface of fifteen similar leaves. Young nursery seedlings of current season's growth were utilized, and leaves of corresponding size and age were used on the various plants.

Following an inoculation period of fifteen days the treated leaves were removed from the plants and the lesions of infection counted. Upper leaf-surface inoculations yielded an average of 18.2 lesions per leaf, while upon those of under-surface treatment there were 85.3 lesions per leaf. Furthermore, at the end of this period many of the lesions on the under leaf-surface were in a conidial fruiting stage, while those of the other type were much less advanced and showed little fruiting. A duplication of this experiment gave similar results. It follows, therefore, that in applying sprays for the control of this disease, caused by *Coccomyces* sp., particular care should be taken to secure good coverage of the lower leaf-surface with a fine mist or fog spray.

Little or no attention has been given to determine a suitable spray solution for protecting nursery stock of *P. serotina* from infection by this fungus. The use of this tree species in reforestation warranted

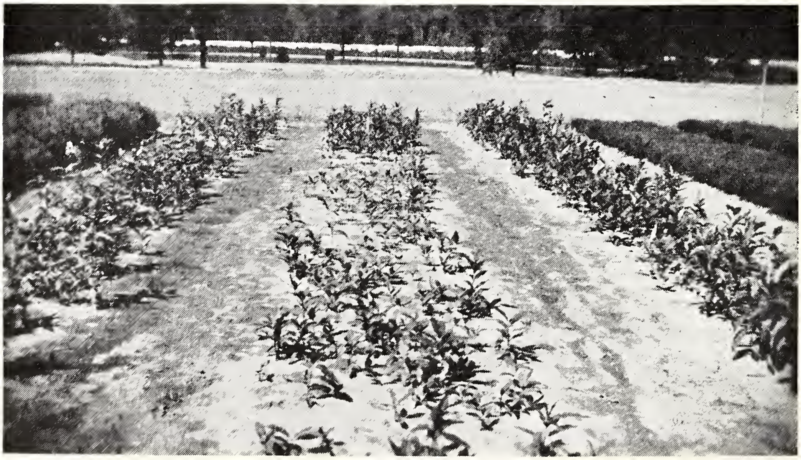

Fig. 1. Center foreground, plot receiving lime sulphur plus ferrous sulphate; control area in center background. Plot to the right received Bordeaux mixture 2-3-50.

experimental work in this direction. It was found that lime sulfur 1-50 plus one and one-fourth pounds of ferrous sulphate was entirely impractical for use on seedling plants. Despite the previous recommendation ol this solution[1] all of the plants in this experimental plot were either severely stunted or killed outright (Fig. 1). Two sprays which gave favorable results, using the criteria of foliage protection and freedom from unfavorable affects on plant growth, were copper phosphate and Bordeaux mixture.

The copper phosphate spray was composed of copper phosphate, two pounds, hydrated lime, four pounds, bentonite, two pounds, and water, fifty gallons. (With hand operated sprayers some difficulty is encountered in keeping the solution sufficiently agitated to yield a uniform spray.) The Bordeaux was a standard 2-3-50 formula. Neither of the above sprays entirely prevented leaf infection although seven applications were made at weekly intervals. However, infection in neither case was sufficient to cause premature leaf-fall during the actively growing season for the plant. From the various solutions tested, including several commercial sulfurs, the copper compounds indicate that with further research a successful spray can be developed for the control of leaf-spot on black cherry.

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[1] Hesler, L. R. and H. H. Whetzel. 1924. Manual of fruit diseases. p. 176. Macmillan. New York.

A Phytosociological Study of the Woody Plants Constituting Twenty-five Type Forests of the Illinoian Till Plain in Indiana

SCOTT McCOY, Arsenal Technical H. S., Indianapolis

Introduction

Plant sociological studies have held the attention of European students of plant life for many years but have had little consideration in the United States until recent times when H. S. Conard and Stanley A. Cain gave this study of plant life impetus.

Many of American studies of the relationship of plants to their habitat were published under generalized headings of ecological survey; and they were usually extensive rather than intensive, empirical rather than quantitative, and so were not very analytical. This is especially true for Indiana, which Friesner (1937) has aptly called "a critical botanical area." For here are limits of extension of plants from every cardinal point of the compass. It was frequently assumed that because Indiana is a more or less uniform till plain, especially when viewed on a map, the plant cover should also be more or less homogeneous and uniform. That is, however, an erroneous conception, especially when forest types within the deciduous forests are involved. Potzger (1937) has shown that microclimate or local climate is sufficiently important to vary expression in oak-hickory or beech-maple type by the small difference of north or south exposures of ridges.

The present study is concerned with the forests on the topographically uniform Illinoian till plain which has an eastern and western lobe extending southward beyond the later-deposited Wisconsin glacial till. A considerable portion of the eastern lobe is known as the "flats" area. The soil is more or less uniform, and so one might expect a striking uniformity in forest type.

Various plant geographers of the past apparently considered such an assumption the true status.

Weaver and Clements (1929) give two particular climax forest types as applicable to the general region under study, these being the beech-maple and oak-hickory types.

A committee of the Society of American Foresters (1932) places the "flats" of Indiana into the beech type of forest, the beech being pure or predominating.

Zon (1924) placed practically all of Indiana into the oak-hickory type of forest. Such a classification was based on little field study and so has given an incomplete picture of our Indiana forest climaxes.

Gordon (1936) states that the north-central part of Sullivan County, where three of the western lobe forests under study are located, has pure stands of beech, beech-sugar maple, and beech-sugar maple-yellow popular types. Practically all the forests on the eastern lobe, considered in this paper, fall into his beech-sweet gum district. All of these classifications are incorrect, as subsequent data will show.

It is, thus, apparently assumed that the homogeneous Illinoian till plain is characterized by a homogeneous vegetation cover. Investigation of the concepts frequency, density, and fidelity promised most information on the true relationships with respect to the woody species constituting the forests on the Illinoian till plain in Indiana; and so these concepts were stressed in the present study.

The concept fidelity is used here in a modified sense from that given it by Braun-Blanquet and Pavillard. It is used as referring to the regularity of occurrence of a species in twenty-five similar habitat sites but not necessarily with similar vegetation complex, and its degree is expressed in percentage. It is thus, a modification of the diagram presentation of the same concept by Sampson (1930).

Geologic and Physiographic History

The two regions under study are located on the Illinoian till plain, one on the eastern side of the state comprising most of Jackson, Jefferson, Jennings, and Ripley counties and the other on the western side in Davies, Greene, Sullivan, and Vigo counties (Figure 1).

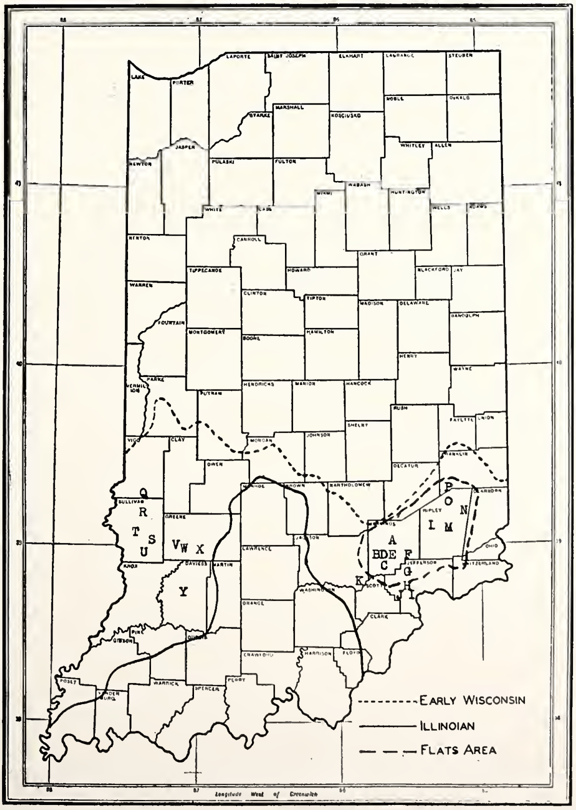

Fig. 1. Glacial boundaries, extent of the "flats" area, and locations of the forest sites studied.

The geologic and physiographic history of Indiana is probably more diverse and complex than one might assume from casual observation and is due to a number of significant geological phenomena of the past, such as series of uplifts and subsequent levelings and periodic crustal stability during which time denudation took place. During Pleistocene times continental glaciation modified most of Indiana and obliterated much of the erosional surface features formed after the Cincinnati Arch uplift. Three glacial invasions are recognized, *viz.*, the Illinoian, Early, and Late Wisconsin. Of these, the Illinoian was the most extensive, reaching the Ohio River but leaving a large triangular area in the south-central part comprising approximately 6,250 acres unglaciated. Most of the surface evidence of the Illinoian glaciation was covered by the moraines and till of the two Wisconsin ice sheets. The two lobes of the Illinoian till plain which are still exposed comprise 3,100 square miles in the eastern lobe and 4,100 square miles in the western lobe (Malott 1922). The soil is extremely leached, consisting chiefly of a whitish clay with usual poor drainage. The monotonously featureless plain of the eastern lobe has coined for it the term "flats" area. Although, as a whole, the western area has a somewhat better drainage, it has essentially the same soil characteristics so that one might suggest a western "flats" area.

Climatic Factors

The climate always presents an important group of factors affecting vegetation, and the areas under study are no exception. The precipitation and temperature data for the areas under study were compiled from the work of Martin (1933), data taken from weather bureau stations nearest a respective group of forests.

Edaphic Factors

The typical soil structure of the Illinoian glacial drift is a compact whitish clay, and most of the soil where the twenty-five forests under study were located was of this type. Variants of other soil types were a yellowish clay, sandy clay mixture, grayish clay, and a black loam.

This whitish clay soil has a tendency to become rather compact at the surface and to form a hardpan layer beneath. The very fine texture of the soil and the presence of the hardpan layer permit only a limited amount of subsoil drainage.

There was very little surface drainage in most of the twenty-five forests. The rather level topography and the compactness of the soil are pertinent factors in making the soil water-logged. In general, roadside and other drainage ditches have had some effect on the water table level.

Methods and Type Forest Locations

Twenty-five forests, sixteen on the eastern lobe and nine on the western lobe, were selected for this study. It was attempted to select the most representative and least disturbed forests of the Illinoian till plain which could be found.

Twenty quadrats, ten by ten meters, were run in each of these forests. Usually two lines of ten quadrats each were run. All woody stems one inch and over DBH. were measured. All stems three feet and over in height were included in the density tabulation. The shrubs were tabulated for frequency but not for density. Deam's books (1924, 1931) on Indiana shrubs and trees were the chief sources of the nomenclature used.

All the forests on the eastern lobe of the till plain, with the exception of forests J and P, are on very level lands with practically no surface drainage. Most of these are in the so-called "flats" area of eastern Indiana. Here the glacial drift (Malott, 1922) varies in depth from practically nothing, where it has been removed by subsequent erosion, to over 100 feet. On the average it is less than 25 feet in depth. Much of the drift-covered portion of southeastern Indiana is exceptionally flat, still exhibiting the characteristics of a featureless ground moraine. The deeper drift occupies the pre-glacial valleys.

Topography where the forests on the western lobe are located is similar to that of the eastern lobe with the exception of forest R, which has rather good surface drainage, and X, which has excellent surface drainage.

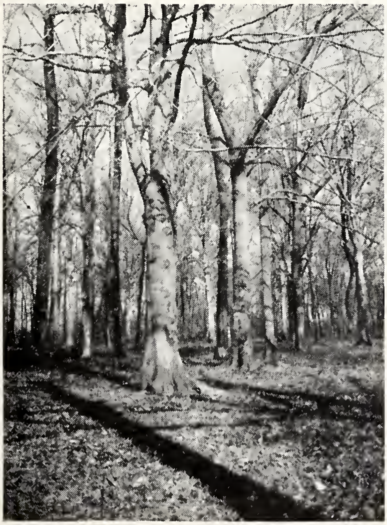

Fig. 2. Some of the few beech present in forest T, Sullivan County. (All photographs by Dr. J. E. Potzger, Jan. 31, 1938.)

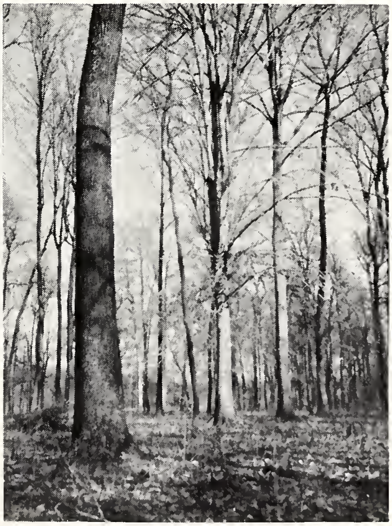

Fig. 3. Open park-like area in Forest T, Sullivan County. Pasturing has reduced the number of young stems.

Observations and Results

Precipitation and temperature.—The records which were consulted for these two areas covered, in most cases, more than 30 years and in some cases up to 45 years, all terminating with the year 1930. These records show very little difference in the average monthly and annual precipitation for the two areas. The average annual precipitation for the eastern lobe is 42.95 inches and that for the western lobe 39.10 inches, a difference of 3.85 inches in the annual precipitation; however, for the growing season from April to September, inclusive, there is a difference of only 0.83 inches, this in favor of the eastern lobe.

The records for average temperature show even less difference between the two areas. For March, May, and September it is the same for both lobes for the months February, April, June, July, August, and November there is a difference of only .3 of a degree or less.

Soil.—County location (Fig. 1) and brief description of the 25 type forests follow:

Forest	County	Soil	Surface Drainage	Disturbance
A	Jennings	fine light clay	little	none
B	Jennings	fine whitish clay	good	none
C	Jennings	fine whitish clay	poor	severe pasturing
D	Jennings	fine whitish clay	fair	very little
E	Jennings	fine whitish clay	very little	none noticed
F	Jennings	fine whitish clay	very little	some, years ago
G	Jefferson	fine whitish clay	good	very little
H	Jefferson	fine whitish clay	very poor	very little
I	Jefferson	fine whitish clay	very poor	completely cut over 28 years ago, now cattle range
J	Jefferson	yellow clay type	very good	none
K	Jackson	fine whitish clay	none	slight cutting
L	Ripley	fine whitish clay	some	pasturing and cutting
M	Ripley	fine whitish clay	very little	years ago, cutting
N	Ripley	fine whitish clay	fair	pasturing and cutting
O	Ripley	fine whitish clay	very little	some recent cutting
P	Franklin	yellow clay	very good	cutting, years ago
Q	Vigo	gray clay	very little	some cutting
R	Sullivan	gray clay	rather good	cutting, years ago
S	Sullivan	light gray clay	very little	very little
T	Sullivan	light gray clay	rather good	pasturing
U	Sullivan	gray clay	fair	pasturing
V	Greene	black loam	none	very young forest, no recent disturbance
W	Greene	light clay	none	pasturing and cutting
X	Greene	sand clay mixture	good	pasturing
Y	Daviess	black loam	fair	by flood waters

The soil, with the exception of that in forest J on the eastern lobe and probably V and X on the western lobe, is practically of the same whitish texture, which in level uneroded sites makes for water-logged conditions. That the soil is water-logged at times is shown by the shallow root systems of such trees as beech and elm, many of their roots having their upper surfaces above the ground for some distance from the tree trunks (Fig. 4). Braun (1936) reports this same condition in certain forests on the Illinoian till plain in Ohio.

No tests were made for soil acidity on the western lobe, but the author (1937) found that the acidity for the soil in forest F on the eastern lobe ranged from pH 4.8 to 5.6 at the surface, 4.8 to 5.4 at

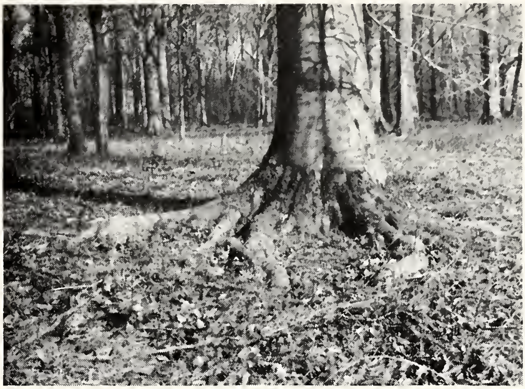

Fig. 4. Showing exposure of beech roots in forest T, Sullivan County.

the three-inch level, and 4.5 to 5.2 for the twelve-inch level. Braun (1936) reported practically the same acidity range for the soil in similar areas in Ohio.

Size classes of the woody plants; frequency, fidelity, density.—The results of the field study relative density, DBH., and subsequent division into size classes are given in Tables I to V, inclusive. The frequency and density of species in the large tree class for both lobes are shown in Table VI. The fidelity of the species in the large tree class for both lobes is shown in Table VII. The frequency and fidelity of species occurring in areas with good and poor surface drainage on both the eastern and western lobes are shown in Table VIII.

TABLE I.—Size Classes, Forests A to E

Species	A						B						C						D						E					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum	202	132												1	1	1									2	3	9	8	2	
A. saccharum							584	63		1									96	56	6	1		1	31	10				
Carya cordiformis																									6					
C. glabra																									2		1			
C. laciniosa	6						3													1										
C. ovata	16	7					5	3						3		2	2	1	14						113	25	5	1		
Fagus grandifolia							153	16		1	9	3		5	2	24	22		77	21	1	2	6	2	73					
Fraxinus americana							1	1		1															15	1				
F. biltmoreana							50	4					1						17	22										
F. lanceolata							35	7											15	14					95					
F. nigra		1																												
Juglans nigra								1		1																				
Liquidambar Styraciflua	16	110	9				72	3			1	1	5	6	1	1	6		9	3		1			4	2	5	8	1	
Liriodendron Tulipifera							18	15				1								5										
Nyssa sylvatica	29	66					1	1						1						1	1				13	6	7	1		
Platanus occidentalis		2					1				1																			
Prunus serotina	1						3												3	2										
Quercus alba		5	2				1																		48	3				
Q. bicolor																									2					
Q. borealis maxima																				1										
Q. palustris	9	60	54	2																										
Q. velutina	1	4																												
Ulmus americana							9	1																						
U. racemosa	210	109											5	2					3	9	2	1			18				1	

a—under 1 inch DBH.
b—1 to 5 inches DBH.
c—6 to 10 inches DBH.
d—11 to 15 inches DBH.
e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE II.—Size Classes, Forests F to J

Species	F						G						H						I						J					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum	91	112	4	1			19	9					19	26	9	8			1	6	7				7	5				
A. saccharum		2					30	1																	121	102	2	1	1	
Carya cordiformis																									2	1				
C. glabra																				3					23	28	5	4		
C. laciniosa							1						4							6	1									
C. ovata	24	19					76	41					8							3					10	10	3			
C. tomentosa																									2		1			
Fagus grandifolia	6	16	2				305	51		1	12	1	163	30	1	1	8	1							27	36	2	2		1
Fraxinus americana							2																							
F. biltmoreana							3						6	1	1										16	3			1	
F. lanceolata	3	7																							12					
F. nigra													1																	
F. profunda	1																													
Juglans nigra																												1		
Liquidambar Styraciflua	32	104	3	2			421	130		2	2		12	3	7	3	1	1	9	164	75	1								
Liriodendron Tulipifera	33	63	1	1			10	18	6	3		1	8	1	1														2	
Nyssa sylvatica	45	34	2				7	3					35	13	5	1	1	1	34	216	6				4	2	2			
Platanus occidentalis		2																				1								
Prunus serotina	3	2					31	9	1				1												8	1				
Quercus alba		3					14	8	3				17	7			1			22	20				9	21	6	2	3	
Q. bicolor							4													9	11									
Q. borealis maxima	2	3					2	1					8	1	2					3	1				1	4				
Q. palustris	7	36							1				1		1	1				1	6									
Q. Prinus	1	1					8	4			1			2	1															
Q. velutina																									9	1	1	2	3	
Ulmus americana	19	16	1											1												3				
U. fulva													1												3	1				
U. racemosa	5	9	1	1			35	26	2				12	9	1				5	3	1									

a—under 1 inch DBH.
b—1 to 5 inches DBH.
c—6 to 10 inches DBH.
d—11 to 15 inches DBH.
e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE III.—Size Classes, Forests K to O

Species	K						L						M						N						O					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum	284	5	5		1			1	3	4	3		6	7	9	6			1		4	2			16	6	2	1	3	
Carya laciniosa	10	2																												
C. ovata	11	2					2			1	1			5		1	3		36	5	1		4		43	8				
Fagus grandifolia			1	5	7			2	2	10	10		12	38	1	7	12		37	7	2	6	19	3	70	12	11	15	4	
Fraxinus americana																			6	2					38	8		1	1	
F. lanceolata							1																							
F. profunda														3	1															
Liquidambar Styraciflua	115	14	3	2					1					5	3				26	7	4	8	1	2	61	4	2	7	1	1
Liriodendron Tulipifera															1	1			1		2	6					1	2		
Nyssa sylvatica	77	10	1	2				3	1	1				4	1	1	1		8	4			4		36	12	4	1		
Prunus serotina	9																						1		3					
Quercus alba	30	42		2				4	4	4	2			1	1	1	1				2			1	2			1	1	5
Q. bicolor		7																												
Q. borealis maxima	16	10	1		1					2				3						1					3	1	1		2	2
Q. palustris	14	13	2	2	1					2	2	6		2	1	1	2	2												
Q. velutina																							1							
Ulmus americana																				1		2			39	21	2		1	2
U. racemosa	2	6							2					6	1	1			3	1										

a—under 1 inch DBH.
b—1 to 5 inches DBH.
c—6 to 10 inches DBH.
d—11 to 15 inches DBH.
e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE IV.—Size Classes, Forests P to T

Species	P						Q						R						S						T					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum											1		4		1		5	1											1	
A. saccharum	227	82	2	1			2												1						59	5	1	2	2	
Carya cordiformis	1																1				1									
C. glabra	2	2	2	1	3																									
C. laciniosa							11			2			15	18			1		5	1					6					
C. ovalis								1		1				1							2	3	2							
C. ovata	4	2					23	3	5	1	1		16	8			1		4	21	2	4			8	9	7	3	1	
C. tomentosa		9	4	3	1		23	1	5	7	1	2	2			1														
Celtis occidentalis							12																							
Fagus grandifolia	22	8	1	3	10	1																			3	1	1	1	8	
Fraxinus americana	19	7	1	1			17	1					25	34	1				1	2	1									
F. lanceolata							25	5	1				3	1					24	2					54	5	3	1	1	
F. profunda													22	5																
Gleditsia triacanthos																2														
Juglans nigra							7	3						5		2										2	1	2		
Liquidambar Styraciflua						1																				3	3	4	8	
Liriodendron Tulipifera		3	6		1	1	11					1																4	2	
Nyssa sylvatica	56	25	4	1	5	1	8	2							1				32	21	5									
Prunus serotina	14	15					30	13					32	19					5											
Quercus alba													13	2	1	2	2	1		3	6	7	6			2	1			1
Q. bicolor													2	2			1			4	1	3	1							
Q. borealis maxima		2		2	1											2	4	1												
Q. imbricaria																				8	2	2	3							
Q. palustris																		1		2		2	3							
Q. velutina		1		3			2	1	2	2	8	1	3			2	5			5								1	4	
Ulmus americana			1	1			13	2					66	12					2											
U. fulva		2											56	10		2	1		3						5				1	
U. racemosa							3	2					37	40					2	2	1				29	6	2	3		

a—under 1 inch DBH.
b—1 to 5 inches DBH.
c—6 to 10 inches DBH.
d—11 to 15 inches DBH.
e—16 to 25 inches DBH.
f—over 25 inches DBH.

TABLE V.—Size Classes, Forests U to Y

Species	U						V						W						X						Y					
	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Acer rubrum			1								1		4	5											61	26	4	3		
A. saccharinum							72	55	21	2	3																			
A. saccharum	4			1															103	49	1	1								
Carya cordiformis							4												5	3										
C. glabra																			7	9	5									
C. ovata	52	76	19				2	1					93	21		1	5	1	12	46	6	1			2			1		
C. tomentosa				1									1	1						8	1									
Fagus grandifolia		2	1																	1										
Fraxinus americana		2																	23	11	16	2	2							
F. biltmoreana																			1											
F. lanceolata														1					3	3		1								
F. profunda							56	54	4	2															93	24	15	3		
F. quadrangulata							1																							
Gleditsia triacanthos								4	2																1					
Liquidambar Styraciflua																									2		1	1		
Nyssa sylvatica	38	15	6	1															1	2	2									
Platanus occidentalis							1																		1				1	
Populus heterophylla										1																1		1		
Prunus serotina	28	5											42	11						1										
Quercus alba			1	1																3	2	3	6	1						
Q. bicolor													18	7	5	11	1	1								1	5	4	8	
Q. borealis maxima													1														2			
Q. imbricaria				12	5								34	19		5	4			1										
Q. Muhlenbergii																						1								
Q. palustris							45	99	18		1		24	32			2	1							11	5	8	11	2	1
Q. stellata	1		1	2																										
Q. velutina				1	15	1																	1							
Ulmus fulva													1						24	30	1									
U. racemosa	38	3					19	29	5	1	1		18	21					2	7	1				33	31	4	1	2	
U. americana																			3	4										

a—under 1 inch DBH.
b—1 to 5 inches DBH.
c—6 to 10 inches DBH.
d—11 to 15 inches DBH.
e—16 to 25 inches DB H.
f—over 25 inches DBH.

TABLE VI.—Frequency and Density of Species in the Large Tree Class Occurring in 16 Type Forests (Eastern Lobe) and 9 (Western Lobe) of the Illinoian Till Plain in Indiana.

Species	Eastern Lobe		Western Lobe		Total Both Areas	
	F. I.	Density	F. I.	Density	F. I.	Density
Acer rubrum	43.8	1,054	16.7	118	34.0	1,172
A. saccharinum			8.9	156	3.2	156
A. saccharum	30.6	1,412	15.0	240	25.6	1,652
Carya cordiformis	2.2	9	5.0	15	3.2	24
C. glabra	9.7	75	6.1	22	8.4	97
C. laciniosa	5.6	34	10.0	59	7.2	93
C. ovalis			3.3	10	1.2	10
C. ovata	41.6	569	53.9	407	46.0	976
C. tomentosa	.6	9	9.5	65	3.8	74
Celtis occidentalis			2.2	12	.8	12
Fagus grandifolia	71.9	1,421	6.1	18	48.2	1,439
Fraxinus americana	13.8	115	17.8	128	15.2	243
F. biltmoreana	12.5	125	.6	1	8.2	126
F. lanceolata	17.0	267	22.2	55	18.6	322
F. nigra	1.6	5			2.8	5
F. profunda	1.3	5	22.8	278	9.0	283
F. quadrangulata	.3	1	.6	1	.4	2
Gleditsia triacanthos			1.7	9	.6	9
Juglans nigra	1.0	3	2.2	22	1.4	25
Liquidambar Styraciflua	55.6	1,506	9.5	22	39.0	1,528
Liriodendron Tulipifera	20.9	212	4.4	18	15.0	230
Nyssa sylvatica	46.3	704	16.7	130	35.8	734
Platanus occidentalis	1.6	5	2.2	5	1.8	10
Populus heterophylla			1.7	3	.6	3
Prunus serotina	16.6	120	17.8	173	17.0	293
Quercus alba	33.1	238	26.1	137	30.6	375
Q. bicolor	3.4	49	17.2	60	8.4	109
Q. borealis maxima	17.5	75	6.1	12	13.4	87
Q. imbricaria			18.0	95	6.4	95
Q. Muhlenbergii			.6	1	.2	1
Q. palustris	19.1	229	26.6	268	21.8	497
Q. Prinus	3.8	18			2.4	18
Q. stellata			1.7	4	.6	4
Q. velutina	4.1	26	17.2	54	8.8	80
Ulmus americana	7.5	120	9.4	102	8.2	222
U. fulva	1.9	8	15.0	134	6.6	142
U. racemosa	36.2	491	45.5	341	39.6	832
Total Density		8,805		3,175		11,980

TABLE VII.—Fidelity (in per cent) of Woody Species, Large Tree Class, Constituting 25 Type Forests of Illinoian Till Plain in Indiana.

Species	Eastern Lobe	Western Lobe	All Areas
Acer rubrum	81	77	80
A. saccharinum		11	4
A. saccharum	44	55	48
Carya cordiformis	19	44	28
C. glabra	25	11	20
C. laciniosa	44	44	44
C. ovalis		33	12
C. ovata	100	100	100
C. tomentosa	6	44	20
Celtis occidentalis		11	4
Fagus grandifolia	88	33	68
Fraxinus americana	38	55	44
F. biltmoreana	50	11	36
F. lanceolata	38	66	48
F. nigra	19		12
F. profunda	12	33	20
F. quadrangulata	6	11	8
Gleditsia triacanthos		33	12
Juglans nigra	12	33	20
Liquidambar Styraciflua	94	22	68
Liriodendron Tulipifera	69	22	52
Nyssa sylvatica	100	55	84
Platanus occidentalis	25	33	28
Populus heterophylla		22	8
Prunus serotina	75	77	76
Quercus alba	88	88	88
Q. bicolor	25	44	32
Q. borealis maxima	81	33	64
Q. imbricaria		44	16
Q. Muhlenbergii		11	4
Q. palustris	50	55	52
Q. Prinus	19		12
Q. stellata		11	4
Q. velutina	25	66	40
Ulmus americana	44	44	44
U. fulva	25	55	36
U. racemosa	75	100	84

Analysis of Table II shows that forest A, evidently a comparatively young forest, has 986 stems ranging in size up to 5 inches DBH., 67 between 6 and 15 inches, 65 of these being 10 inches or under. Forest B has 1,051 stems in the two lower size classes and only 20 stems above 5 inches DBH. In this forest the surface drainage is rather good. No pasturing has occurred in both of these forests so that reproduction is unhampered by cultural influences. Forest C is subjected to almost continual pasturing. Here are only 29 stems in the two lower size-classes and 63 in the upper classes, the majority being above 15 inches DBH. Forest E is a mature stand on rather level land. It has 472 stems in the two lower size-classes. Seventy-three of these are beech, indicating that beech is just coming in. Forest I was completely cut over 28 years ago, but the beech has not as yet come in although it is present in the older forests in the vicinity. Here the oaks and sweet and sour gums are the dominant species. Forest J has excellent surface drainage, and here white and black oak and four species of Carya, namely *C. cordiformis*, *C. tomentosa*, *C. ovata*, and particularly *C. glabra*, are giving the beech and sugar maple serious competition. On the western lobe beech is poorly represented; the dominant species seem to be beech, oak, and hickory, with considerable sugar maple in a few forests. On the drier sites red elm may be found.

TABLE VIII.—The Frequency and Fidelity of Species Occurring in Areas with Good and Poor Surface Drainage on the Eastern and Western Lobes of the Illinoian Till Plain.

Species	Eastern Lobe				Western Lobe			
	Frequency Gullying		Fidelity Gullying		Frequency Gullying		Fidelity Gullying	
	Yes	No	Yes	No	Yes	No	Yes	No
Acer rubrum	16.7	60.5	50	100	8.3	20.8	66	83
A. saccharinum	......	......	......	......	......	13.3	......	17
A. saccharum	69.2	7.5	83	20	38.3	3.3	66	50
Carya cordiformis	3.3	1.5	33	10	11.7	1.7	66	33
C. glabra	22.5	2.0	33	20	18.3	......	33	......
C. laciniosa	3.3	7.0	50	40	13.3	8.3	66	33
C. ovalis	......	......	......	......	1.7	4.2	33	33
C. ovata	41.7	41.5	100	100	63.3	49.2	100	100
C. tomentosa	1.7	......	17	......	10.0	9.2	66	33
Celtis occidentalis	......	......	......	......	......	3.3	......	33
Fagus grandifolia	85.0	64.0	100	80	15.0	1.7	66	17
Fraxinus americana	19.2	11.5	68	20	36.6	8.3	66	50
Fraxinus biltmoreana	27.5	3.5	68	30	1.7	......	33	......
F. lanceolata	23.3	12.5	50	30	41.6	12.5	100	50
F. nigra	......	2.5	......	30	6.7	4.2	33	17
F. profunda	......	2.0	......	20	5.0	31.7	33	33
F. quadrangulata	......	.5	......	10	......	.8	......	17
Gleditsia triacanthos	......	......	......	......	1.7	1.7	33	33
Juglans nigra	2.5	......	33	......	6.6	1.7	33	33
LiquidambarStyraciflua	39.2	65.5	83	100	21.7	3.3	33	17
Liriodendron Tulipifera	27.5	17.0	100	50	5.0	4.2	33	17
Nyssa sylvatica	32.5	55.0	100	100	5.0	22.5	66	50
Platanus occidentalis	.8	2.0	17	30	1.7	2.5	33	33
Populus heterophylla	......	......	......	......	......	2.5	......	33
Prunus serotina	29.2	9.0	100	60	16.7	26.7	66	68
Quercus alba	26.7	32.0	83	90	33.3	22.5	100	83
Q. bicolor	.8	5.0	17	30	3.3	24.2	33	50
Q. borealis maxima	9.2	22.5	83	80	13.3	2.5	66	33
Q. imbricaria	......	......	......	......	1.6	25.8	33	50
Q. Muhlenbergii	......	......	......	......	1.6	......	33	......
Q. palustris	.8	30.0	17	70	1.6	39.2	33	68
Q. Prinus	5.8	2.5	17	20	......	......	......	......
Q. stellata	......	......	......	......	......	2.5	......	17
Q. velutina	10.0	1.5	33	20	30.0	18.3	100	50
Ulmus americana	10.0	6.5	87	10	20.0	4.2	66	33
Ulmus fulva	3.3	1.0	33	20	33.3	5.8	100	50
U. racemosa	21.7	44.0	50	100	41.6	47.5	100	83

A comparison of the frequency, density, and fidelity of the ten leading species on the two lobes is shown in Table IX.

TABLE IX.—Showing 10 Species Highest in Frequency, Density, and Fidelity.

	Eastern Lobe		Western Lobe	
	FREQUENCY			
		Per cent		Per cent
1	Fagus grandifolia	71.9	Carya ovata	53.9
2	Liquidambar Styraciflua	55.6	Ulmus racemosa	45.5
3	Nyssa sylvatica	46.3	Quercus palustris	26.6
4	Acer rubrum	43.8	Quercus alba	26.1
5	Carya ovata	41.6	Fraxinus profunda	22.8
6	Ulmus racemosa	36.2	Fraxinus lanceolata	22.2
7	Quercus alba	33.1	Quercus imbricaria	18.0
8	Acer saccharum	30.6	Prunus serotina	17.8
9	Liriodendron Tulipifera	20.9	Fraxinus americana	17.8
10	Quercus palustris	19.1	Quercus velutina	17.2
	DENSITY			
1	Liquidambar Styraciflua	1,506	Carya ovata	407
2	Fagus grandifolia	1,421	Ulmus racemosa	341
3	Acer saccharum	1,412	Fraxinus profunda	278
4	Acer rubrum	1,054	Quercus parlustris	268
5	Nyssa sylvatica	704	Acer saccharum	240
6	Carya ovata	569	Prunus serotina	173
7	Ulmus racemosa	491	Acer saccharinum	156
8	Fraxinus lanceolata	267	Quercus alba	137
9	Quercus alba	238	Ulmus fulva	134
10	Quercus palustris	229	Nyssa sylvatica	130
	FIDELITY			
1	Carya ovata	100	Carya ovata	100
2	Nyssa sylvatica	100	Ulmus racemosa	100
3	Liquidambar Styaciflua	94	Quercus alba	88
4	Quercus alba	88	Acer rubrum	77
5	Fagus grandifolia	88	Prunus serotina	77
6	Acer rubrum	81	Fraxinus lanceolata	66
7	Quercus borealis maxima	81	Quercus velutina	66
8	Ulmus racemosa	75	Nyssa sylvatica	55
9	Prunus serotina	75	Quercus palustris	55
10	Liriodendron Tulipifera	69	Acer saccharum	55

With conclusions based on data from forests A, B, and D, it would seem that sweet gum and pin oak are the first to invade level, water-logged land. Pin oak shows greatest dominance with 56 of the 67 stems over five inches DBH. Later red maple, sour gum, cork elm, and shellbark hickory come in. In forest D surface drainage is better than in Forest A and the stand is more mature. Here pin oak has passed out completely, cork elm is very much reduced in density, sweet gum, red maple, sour gum, and shellbark hickory are remaining but with a much reduced frequency on the part of the first three mentioned, inasmuch as white oak, certain ashes, and hickories, as well as beech, are just coming in along with the sugar maple. In forest B, a rather mature forest with good surface drainage, beech is clearly the dominant tree; however, sugar maple has by far the greater reproduction. Red maple and cork elm have disappeared, and white elm and tulip poplar have come in.

Discussion

Most investigators associated with the geographically delimited "flats" region of southeastern Indiana a beech-sweet gum forest cover. This is a generalized statement on plant sociology for a highly indefinite area as far as plant habitat is concerned. Quantitative field data are almost a necessity for a fairly accurate analysis of the conditions which control and the expression of forest which they induce. The best quantitative data were expected from an analysis of the combination study of frequency, density, and fidelity, especially to ascertain whether or not the more or less uniform Illinoian till plain region had a corresponding homogeneous forest cover; and for this reason these sociological concepts were stressed in the present study.

In a general way we might say beech-sweet gum make up much of the crown cover of the forests on the Illinoian till plain in southeastern Indiana; but micro-climate here imposes striking variations, too. As shown by Table IV, beech shows only a frequency index of 71.9 and sweet gum one of 55.6. In fidelity in appearance in the different forest stands (Table VII), beech shows only 88% and sweet gum 94%. That means that even in three stands or forests in this region beech and sweet gum were not present in the forest cover. In density (Tables I, II, VI) both of these two species are prominent in large size-classes, as well as in the younger growth. Beech with 1,421 stems and sweet gum with 1,506 stems in 16 stands considered control much of the crown cover.

It is at once quite evident, when considering the nine forests on the western lobe of the Illinoian till plain, that the habitat here must be strikingly different from that on the eastern lobe. Beech has a frequency of only 6.1% and sweet gum 9.5%. Density also drops into insignificance. Fidelity is a little higher than frequency, but both of the above named species are present only in less than one-third of the nine stands. This clearly shows that the two lobes are strikingly different as habitat sites. Gordon (1936) classifies the typical forest of this region (western lobe) as beech-sugar maple or beech-sugar maple-yellow poplar. The present study shows that all of these species are in the lowest frequency, density, and fidelity classes (Table VI) and thus play a secondary role in the crown cover of these forests. A study of Table VI will show that the forests are outstanding by heterogeneity, no few species controlling dominance over crown cover as in the forests on the eastern lobe. This at once indicates a heterogeneous habitat. In the highest frequency classes are *Ulmus racemosa* (45%), *Carya ovata* (53.9%), and several species of ash and oak with a F. I. in the lower twenties. Sugar maple has a F. I. of 15% and tulip poplar only 4.4%. With such low frequency, fidelity, and density we would hardly be justified to consider them as key species typifying forest cover. *Carya ovata* has the greatest density of any species (407 stems), and *Ulmus racemosa* is second with a total of 341 stems (Table IX). These same two species have a 100% fidelity; *Quercus alba* has a fidelity of 88%. As a whole, the forests on the western lobe are more of the oak-hickory-elm type; but as previously stated, the region as a whole is marked by a heterogeneous crown control. So these two topographically similar regions are not in the least similar in plant cover.

There are, of course, various other comparisons that could be made between the forest complexes of these two regions, notably among them the fact that *Nyssa sylvatica* and *Acer rubrum* play an important part in the forests on the eastern lobe but are unimportant in forests on the western lobe, the tables on density, frequency, and fidelity showing these differences to full advantage. Note especially the summary presentation in Table IX.

Considering the 25 forests, we find that the only species with 100% fidelity is *Carya ovata* (Table VII); nearest this species is *Quercus alba* (84%), which indicates a greater potentiality for habitats in these species and suggests at the same time that the more localized dominants like beech, sugar maple, and sweet gum may represent more closely confined sere dominants in a succession cycle with optimum conditions pictured where density is high in both mature growth and reproduction. One of the environmental controls of this variation in forest type is indicated in the comparison of sites with and without gullying shown in Table VIII; but we must admit that, when considering the problem of plant sociology on the 25 sites of the Illinoian till plain in Indiana as a whole, we are confronted by a number of situations which are not easily explained by mere data from the vegetational complex. The habitats to all appearances are very much alike. Macroclimatic factors are similar for the whole season, and for this reason temperature and precipitation *per se* are probably not the primary cause of variation in forest types in these Illinoian till plain areas. The real cause must be sought for in edaphic factors. Soil texture, too, is rather uniform, and topography shows little variation; but the forest associations vary considerably on the different sites. Especially baffling is the distribution of beech. It may be a prominent dominant in water-logged sites as in forest F, associated there with sweet gum, sour gum, pin oak, and red maple, occupying the slightly elevated hummocks; or it may be co-dominant with sugar maple and white oak on well-drained mesophytic sites, as in forest B. This greater potentiality for habitat variation in beech was described by Potzger (1933) for the flood-plain and north-facing slopes of flanking uplands in the Salt Creek Valley in Monroe County, Indiana.

Pin oak and sweet gum are limited to wet sites, although sour gum and red maple have such a wide range of adaptability to habitat that they might be expected in any habitat, as Sampson (1930) also shows for northeastern Ohio.

The quantitative data collected during the present investigation do not support entirely the classifications by a Committee of the Society of American Foresters (1932) and Weaver and Clements (1929), and they do not agree at all with the classifications by Gordon (1936) and Zon (1924).

As already pointed out, variation in forest association is especially marked on the western lobe, for no one species here shows a high per cent fidelity. Even though advantage of centers from which migration might take place can account for some heterogeneity in forest associations, it does not solve the whole problem, for time must eventually have modified such advantages. The real cause must be sought in hidden microclimatic differences in the habitat. If exposure of slope may initiate a sharp dividing line between beech-maple and oak-hickory in central Indiana, slight variations in edaphic or meteorological conditions may well account for the differences in the forests on the western lobe. This region is nearer the prairie influences so that the similarity in precipitation between the two lobes may well be eliminated by higher evaporation on the western lobe. Evaporation differences make beech-maple forests possible in northern Michigan with a rainfall of 25 inches and in Indiana with 40 to 45 inches. Rainfall in the uniform prairie formation ranges from 20 to 40 inches (Weaver and Clements, 1929). Yet in the end, evaporation difference unifies the effect on the plant cover.

Physiographic characteristics, such as the regional slope of the strata to the southwest and the proximity of the Wabash river drainage, might have developed better subsoil drainage in this western region than exists on the eastern lobe. Borings in Sullivan county disclosed sand and gravel in the lower layers of the soil and this would favor efficient subsoil drainage.

It appears that it is not the soil texture which exerts a selective influence on species and associations but rather the water relationship of the soil; and the associations will vary as sites vary in degree of drainage, approximating, thus, forest types controlled by physiography and topography in the unglaciated section of Indiana.

Taking the Illinoian till plain as a whole, there is no one species nor association of species which by their fidelity might be termed indicators of Illinoian till plain habitat sites. On the contrary, even though the two lobes are marked by topographic uniformity, vegetationally they present a series of habitat sites which range from late stages of a hydrosere to late stages of a xerosere. Results shown in Tables VIII and XI on frequency, density, and fidelity of the dominant species of the 16 forests on the eastern lobe indicate that pin oak, sweet gum, sour gum, cork elm, and red maple are early invaders of the level, poorly drained, undissected lands. As soon as hummocks raise the soil ten to twelve inches above the water table, beech, white oak, and shellbark hickory invade; and, with increasing drainage, sugar maple, tulip poplar, hickories, and oaks initiate the succession to a typical mixed mesophytic forest.

The forests on the western lobe can hardly be compared with those of the eastern lobe as to phytosociological complex unless they are considered an indication of succession from mesophytic to the drier site oak-hickory type of forest cover, for they are already expressions of such forest type.

Completing the indicated succession of the forests on the Illinoian till plain, we would have, beginning with undrained areas, invasion by pin oak, sweet gum, sour gum, cork elm, red maple to beech, white oak, and shellbark hickory, associated with the former species, to beech, maple, hickories, and mesophytic oaks, to typical oak-hickory dominance, initiated and maintained by degree of drainage of the soil. The shrub layer is poorly expressed in all stages of succession. Thus, when the vegetation of the Illinoian till plain as a whole is in question, all the various stages and forest types may be encountered.

Here, too, applies the statement by Nichols (1929) "It should be borne in mind that in attempting to classify the facts of nature, we are dealing with merging phenomena."

Summary and Conclusions

1. A phytosociological study was made of the woody species in 25 forests on the Illinoian till plain in Indiana. Sixteen of these were located on the eastern lobe and nine on the western lobe.
2. The topography of the sites ranged from a very level surface without much surface drainage to areas with good surface drainage.
3. Habitat sites on both lobes are very similar as to soil texture, temperature, and precipitation factors.
4. The fine texture of the whitish clay soil is conducive to water-logged conditions where drainage is poor.
5. Forest types differ markedly in the various sites, especially with respect to eastern and western lobes.
6. Beech and sweet gum are in low frequency and density classes on the western lobe.
7. Shellbark hickory is the only species with 100% fidelity in the 25 forest sites.
8. Controlling factor in the selection of forest type appeared to be degree of drainage of the soil.
9. Dominant species in the water-logged sites were pin oak, sweet gum, red maple, sour gum, cork elm, and beech.
10. Beech showed a wide range preference with respect to available water in the soil. It invaded the higher hummocks in wet sites and continued as dominant into mesophytic beech-maple sites.
11. Dominants on the mesophytic sites are sugar maple, tulip poplar, pignut hickory, red oak, and beech.
12. With continued dissection of the site, mixed hardwoods gave way to oak-hickory.
13. Forests on the western lobe were predominatingly of the oak-hickory elm type.
14. Species showing greatest fidelity on the eastern lobe were: shellbark hickory 100%, sour gum 100%, sweet gum 94%, beech 88%,

white oak 88%, red maple 81%, red oak 81%, cork elm 75%, black cherry 75%, black oak 66%.

16. Species with highest F.I. on the eastern lobe were: beech 71.9%, sweet gum 55.6%, sour gum 46.3%, red maple 43.8%, shellbark hickory 41.6%.

17. Species with highest F.I. on the western lobe were: shellbark hickory 53.9%, cork elm 45.5%, pin oak 26.6%.

18. It is suggested that less soil water, because of greater evaporation stresses and better subsoil drainage, may account for low frequency and fidelity of beech, sweet gum, and sugar maple in the forests on the western lobe, with resultant oak-hickory-elm control.

Acknowledgments

To the following individuals and groups I am especially indebted:—Dr. R. C. Friesner, for the suggestion of the problem and for his untiring assistance in collecting the field data and his many helpful suggestions; Dr. J. E. Potzger, under whose supervision this work was done, for his many helpful criticisms and suggestions, critical reading of the manuscript, and aid in the field; Dayton Swickard, Byron Moss, Robert Kent, and Matthew Harmon, undergraduate students of the Botany Department, Butler University, who assisted in the field work; the Indiana Academy of Science for financial aid in carrying out the field work.

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(Note: Copies of all Mss. referred to in this paper are on file in the Botanical Library of Butler University, Indianapolis, Indiana.)

Plant Structure as Influenced by Soil Moisture

Charlotte L. Grant, Arsenal Technical Schools, Indianapolis

Introduction

In planning culture methods for a study of the influence of differing quantities of soil moisture upon plant structure, a general review was undertaken of the moisture properties of several soils to be used. These moisture contents in order of decreasing magnitude are (1) water-logged condition, (2) maximum water-holding capacity, as defined by Hilgard (1914) for a column of soil one centimeter high, (3) water-holding capacity for columns of varying height, with four inches predominant, since this was the height to be used in plant cultures, (4) optimum moisture content (the lower limit of plasticity), (5) field capacity, (6) moisture equivalent, (7) permanent wilting percentage, (8) hygroscopic coefficient, and (9) moisture content of air-dry soil. These moisture values for fine (dune) sand, sandy loam, brown silt loam, and black clay loam are exhibited in Table I.

Table I.—Summary of Moisture Properties of Soils

	Fine Sand	Sandy Loam	Brown Silt Loam	Black Clay Loam
Water-logging Percentage	40.66	42.77	61.30	79.22
Hilgard (1 cm.) Water-holding Capacity	32.86	36.80	60.90	78.73
4-inch Water-holding Capacity	26.00	31.70	43.30	57.23
"Optimum Moisture Content"	20.24	25.60	39.80	52.91
Field Capacity	9.8	16.43	26.20	30.00
Moisture Equivalent	6.04	14.88	26.80	33.29
"Safe" value above Permanent Wilting Percentage	4.50	8.50	13.60	16.80
Provisional Permanent Wilting Percentage	2.70	6.64	11.96	14.86
Hygroscopic Coefficient	3.03	5.00	5.82	8.98
Moisture content of Air-dry Soil	0.66	1.42	2.80	7.24

Culture Experiments

On the basis of moisture values determined it is possible to establish a control method for plant cultures employing three ranges of moisture variation—wet, moist, and dry. The upper limit of the high moisture range should not exceed the water-holding capacity of a four-inch column or an excessive wetness will prevail in the bottom part of the four-inch depth of soil in each container. The upper limit of the low moisture range should not be less than the field capacity, or, when water is added to replace that lost from the plants, the bottom soil will not receive any of the water added. The lower limit of the low moisture range must be a safe margin above the value of the permanent wilting percentage. Thus the upper limit of the wet range and the upper and lower limits of the dry range were the starting points. The moist range was spaced equally between the wet and dry. This was accomplished by dividing the interval between the upper limit of the wet and the upper limit of the dry into six equal parts. The upper two of the sixths represent the wet range; the next sixth is the gap between wet and moist ranges; the next two sixths represent the moist range; and the last sixth is the gap between moist and dry ranges. Thus, in each of the three ranges, the soil moisture, though it could not be held constant at a particular percentage, varied only within limits not widely separated, and the moisture values within any one range were at all times different from those in other ranges.

Zinnia (Red Riding Hood variety), Phaseolus (Stringless Green Pod variety), Impatiens (balsam), and Ricinus (castor bean) were selected for growth experiments. No. 2 tin cans which were paraffin-lined and tared to equal weight by drops of liquid paraffin were used throughout the experimental work. Cover lids punched with a central one-half inch hole were also tared to equal weight. The lids were not sealed nor the holes plugged with cotton; the lids thus retarded surface evaporation greatly but did not interfere with the diffusion of gases. This method of preparing the cans for planting is a modification of the method used by Veihmeyer and Hendrickson (1928) in their direct determination of permanent wilting.

Equal weights of an air-dry soil which had been passed through a one-sixteenth-inch mesh screen were placed in the plant containers. Packing was accomplished by dropping each container five times through a distance of three inches. Thirty cans were assigned to Zinnia (ten to each of the three moisture series), and fifteen to Phaseolus, Impatiens, and Ricinus, respectively.

On the basis of oven-dry weight of soil in each container the upper and lower moisture limits were calculated in grams, and water to bring the moisture content to the upper limit was added. By daily weighings and the addition of water at the top to bring to the upper limit when the lower limit was approached or reached, the range of soil moisture for each series was maintained. The alternate loss by transpiration and evaporation and replacement of water by addition at the top approximates field conditions of both watering (by rainfall) and the effect of watering upon the movement of gases in the soil. Furthermore, the wettest layers of soil are brought nearer the source of gaseous supply.

The pot cultures of the wet, moist, and dry series were kept on a large turn-table (to eliminate inequalities of lighting) in a greenhouse with temperature ranging usually between 65°-75°F. Above this turn-table were strong Mazda lamps to extend the winter hours of lighting in early morning and late afternoon.

From the time of expansion of the first leaves, leaf and internode measurements were followed in careful detail. The size and number of flowers were recorded for all plants. Root distribution and abundance were studied in each moisture series.

Material for anatomical study was collected from roots, stems, and leaves. Measurements of tissue thickness and cell size were made with an ocular micrometer ruled in the form of a square.

Fresh and dry weights of both tops and roots were determined for the plants of each culture experiment.

The total amounts of water required by the pot cultures of each moisture series were calculated on the basis of the number of cubic centimeters of water necessary to bring each culture to the upper limit of the particular moisture range when the lower limit had been reached.

Summary of Significant Results

Culture methods involving watering at the top appear definitely superior to bottom watering methods, since in the former the influences of gravity, absorption, and evaporation all tend toward more nearly equable distribution of moisture throughout the soil mass.

All data upon the growth and distribution of roots and the form and size of shoot in the four plants studied indicate that there is an optimum moisture content for growth in soils. Zinnia exhibited best growth and development in the moist range, although approaching the lower values of this range in the finer-textured soils. Plants of Impatiens in the moist series were far superior to those in the other two series. Phaseolus showed a like response although here the optimum appeared to lie toward the upper limit of the moist range. The entire development of Ricinus was best in the wet range.

With the exception of Ricinus, the shoots exhibited a greater size than roots in all plants.

The fresh weight of the roots was greater in the moist series. The greatest loss of weight upon oven-drying likewise took place in roots of the moist series, thus giving the smallest proportion of dry-matter as an end result in the moist series of Phaseolus and Ricinus, but in the dry series of Zinnia and Impatiens.

In all instances the shoots showed an increase in weight over the roots. Both fresh and dry weights of Zinnia, Phaseolus, and Impatiens were greatest in the moist series, but in the wet series for Ricinus.

Number of flower heads and individual ray and disc flowers of Zinnia were greatest in the moist series. This was true also for number of flowers in Impatiens. However, in Phaseolus the number and size of flowers and fruits showed a distinct overlapping between moist and wet series. Branches, where present in any of the plants, were of greater number in the moist series.

Anatomical data from Zinnia indicated a greater diameter of stem in the moist and wet cultures but a greater size and number of xylem vessels and larger vascular bundles in the moist series. However, the bundles were more numerous and the strengthening tissue proportionately greater in the dry series.

The plants of the dry moisture range showed smaller and more compactly arranged cells, a second partially-developed palisade layer, fewer air spaces, a better development of veins, a slightly thicker upper epidermis, and a higher stomatal frequency than plants of the other two series. These features of xerism are attributed solely to the soil moisture conditions, since the plants of all three moisture ranges were kept under the same atmosphere conditions.

The slightly larger number of chloroplasts constantly in evidence throughout the leaf sections of the moist-series plants, together with a greater leaf surface, would effectively indicate a greater photosynthetic surface.

The total water requirement of each plant studied was closely correlated with the developmental and structural response of that plant, thus lending greater emphasis to the conclusion that Zinnia, Phaseolus, Impatiens, and Ricinus have an optimum moisture range for growth.

The essence of the method of moisture control used in these experiments is the recognition that truly constant moisture values are neither possible nor desirable to maintain and that such a condition is practically never found in nature. It is possible, however, to restrict alternations in moisture content within controlled limits. Non-overlapping moisture ranges further enable one to produce an experimental contrast for testing the influence of different soil moisture values.

By this mode of soil-moisture control there is provided a means of exact comparison with soils of varying texture, since, after the required physical determinations of moisture properties have been made, the soil moisture ranges for one texture of soil can be calculated to be exactly equivalent to those for another texture.

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Myxomycetes of Clark County, Indiana, II

WILLIAM D. GRAY, Jeffersonville, Indiana

Several seasons of intensive collecting since the publication of the first list of Clark County myxomycetes (Gray, 1936), have brought to light numerous species not included in the first paper. Thirty-four species and varieties were listed in the former publication, and twenty-seven are included in this one, bringing the total to sixty-one—approximately one-seventh of the total number of known species, according to the Macbride and Martin interpretation (1934). It is recognized that in some cases the value of short local lists is subject to question; however, in the present instance, such lists seem to be justified in view of the fact that there is a marked paucity of literature relevant to the myxomycete flora of Indiana. This fact may be borne out by a systematic search through Macbride and Martin's work which reveals but one Indiana citation (p. 161). It is the hope of the writer eventually to extend this work until a more thorough survey of the state has been made, and, at present, collections from twenty-six counties are at hand.

Specimens are deposited, with the same numbers under which they are listed here, in the herbarium of DePauw University. Species marked with an asterisk are being reported for Indiana for the first time. Thanks are due Dr. G. W. Martin, State University of Iowa, and Mr. Robert Hagelstein, Honorary Curator of Myxomycetes, New York Botanical Garden, for the examination of doubtful specimens.

Arcyria nutans (Bull.) Grev.

A cosmopolitan species first collected in Clark County in 1936 but observed numerous times since. (Nos. 232, 257, 338, 344.)

**Badhamia decipiens* (Curtis) Berk.

Represented by one collection in which the sporangia have been rather severely attacked by a species of Cephalosporium. Since, however, there are no other reports of this species for Indiana, it seems worth while to mention this specimen in spite of its poor condition. The Badhamias are poorly represented in Indiana, reports of but two species having been made by earlier workers. (No. 328.)

Comatricha pulchella (Bab.) Rost.

A minute species, represented by only one collection. Probably frequently overlooked because of its small size. (No. 269.)

Cribraria dictydioides Cooke & Balf.

Listed by Macbride and Martin as the most common Cribraria in the Mississippi valley; collected but twice. Further search should reveal many more fruitings. (Nos. 286, 402.)

**Cribraria elegans* Berk. & Curt.

A delicate species, hitherto unreported for Indiana; represented by one small collection. The writer's specimen No. 306 is also this species but is from Decatur County and as yet has not been reported. (No. 229.)

**Cribraria intricata* Schrad.

Listed as a rare species and collected in the county but twice. Welch's collection from Fountain County, No. W5190, is also this species. (Nos. 331, 335.)

**Diderma effusum* (Schw.) Morgan

Olive (1898) reported var. reticulatum from Montgomery County, but there has been no report of the species itself from the state; it is generally listed as rare in America. (No. 256.)

**Diderma rugosum* (Rex) Macbr.

A rare species reported from very few states; easily recognized by its wrinkled, areolate peridium and by the presence of a large columella. (No. 360.)

Diderma spumarioides Fries

A widely distributed species. (Nos. 363, 367, 393, 398.)

Diderma testaceum (Schrad.) Pers.

Not rare. Occurring generally on fallen leaves (particularly beech) but may also be found on small decayed twigs. (Nos. 342, 346, 349, 354, 362, 384, 387, 392.)

Enteridium rozeanum Wingate

Collected twice, but only once in the typical form. (Nos. 274, 275.)

Hemitrichia serpula (Scop.) Rost.

A species listed as being very common, but collected only once; easily overlooked because of its typical occurrence on the lower surface of decaying wood or fallen bark. (No. 337.)

Ophiotheca chrysosperma Currey

Commonly found on the lower surfaces of pieces of fallen bark; rather easily overlooked, particularly in sparse fruitings, because of the small size of the looped or U-shaped plasmodiocarps and the color of the peridium, which blends with that of the substratum; quite evident when the peridium is ruptured, exposing the bright yellow capillitium. (Nos. 372, 375, 381, 382, 385, 386, 389, 399.)

Physarella oblonga (Berk. & Curt.) Morg.

Very common on decayed logs and stumps, particularly in moist woods along the Ohio River; occurring in the plasmodiocarpous as well as the typical sporangiate form. (Nos. 215, 216, 221, 226, 247, 282, 287, 403.)

Physarum bivalve Pers.

Common on decaying leaves and small twigs and once observed on a low-lying branch of poison ivy. (Nos. 336, 339, 347, 357, 400, 401.)

**Physarum gyrosum* Rost.

Specimen No. 5 was erroneously reported as *P. cinereum* in the first list of Clark County myxomycetes, but has subsequently been determined as this species. This specimen occurred on living grass; two additional fruitings have been found on living moss. (Nos. 5, 356, 358.)

Physarum leucopus Link

Listed as a rare species; collected but once. (No. 327.)

Physarum melleum (Berk. & Br.) Massee

Represented by one collection. (No. 276.)

Physarum notabile Macbr.

This form is listed by Macbride and Martin as an eastern United States species. (No. 277.)

Physarum polycephalum Schw.

A very common species in other regions, but continued search in Clark County has revealed it but once. (No. 285.)

Physarum pusillum (Berk. & Curt.) Lister

A cosmopolitan species. (Nos. 208, 380.)

Physarum tenerum Rex

Occurring frequently in the Arctic Springs region, east of Jeffersonville, although listed as rare. An excellent species for culture work and laboratory demonstration. (Nos. 222, 284.)

Stemonitis herbatica Peck

Occurring on petioles and laminae of fallen leaves of oak and cottonwood; also collected on a living twig of poison ivy. (Nos. 250, 251, 252, 253.)

Trichia affinis deBary

Represented by one rather weathered collection. (No. 369.)

Trichia persimilis Karst.

. Most frequently found under the bark of decaying logs, particularly those of wild cherry. Very abundant in early September, at which time it has been found frequently, both in the plasmodial and mature states, by peeling off the bark of moist, decayed wild cherry logs. In Wisconsin this species has been found on birch logs by the same procedure. (Nos. 235, 242.)

Tubifera ferruginosa (Batsch) Gmel.

Listed in taxonomic works as occurring throughout the northern hemisphere. (No. 206.)

Tubifera stipitata (Berk. & Rav.) Macbr.

Despite continued search for this interesting species, only four fruitings have been found. Apparently not common in Indiana but reported once before by Mutchler (1903) from Kosciusko County. (No. 263.)

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SECTION ON CHEMISTRY

Chairman: Frank V. Graham, Ball State Teachers College

During the greater part of the session of the Section on Chemistry, about 100 to 125 members of the Academy and students of Purdue University were in attendance. The papers which were given are published in full or represented by abstracts below. Professor Herman T. Briscoe, Indiana University, was elected chairman of the section for 1939.

ABSTRACTS

A striking illustration of periodicity among some of the halogens. Frank B. Wade, Shortridge H. S., Indianapolis.—Solutions of iodine in aqueous solutions of KI, KBr, KCl, and KF show a series of colors ranging from the familiar deep brown of the iodine-iodide solution through a lighter brown for the iodine-bromide solution, a still lighter brown for the iodine-bromide solution, and a pale brown for the iodine-fluoride solution. These may be measured in a color comparator. A search of the literature is being made on the solubility of iodine in the various halide solutions, and the other halogens will be studied as to their solubility in halide salts. Values will be plotted against atomic numbers to show periodicity.

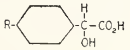
Movie demonstrations in quantitative analysis. M. G. Mellon, Purdue University.—In the usual demonstration of certain techniques in analysis only a few students can be accommodated at one time. The movie film makes such demonstrations easily visible to many. Two films have been prepared for such use. One shows the operations of using a balance to weigh samples, and the other shows the formation and handling of a precipitate which is to be weighed.

A protective coating for zinc surfaces. E. J. Wilhelm, University of Notre Dame.—Zinc has excellent corrosion resistance, but under certain conditions involving contact with excessive moisture a bulky type corrosion product often forms. A protective film capable of preventing this corrosion is produced by immersion in an acid dichromate solution. Its effectiveness is attributed to the presence of a slightly soluble corrosion inhibitor which is released in the presence of water.

An Oxidation Method for the Proof of the Structure of Substituted Mandelic Acids

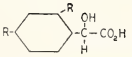
J. L. RIEBSOMER and HOWARD BURKETT, DePauw University

While preparing various substituted mandelic acids[1],[2] it became necessary to find some method to prove the positions of the substituents on the benzene ring. For the simple cases such as



the problem was solved readily by oxidizing the mandelic acid derivative with excess alkaline potassium permanganate. In the case of the para alkyl-substituted mandelic acids this procedure produced terephthallic acid, the dimethyl ester of which is easily prepared and has a convenient melting point of 140°C.[3]

But when the problem is more complex in such a case as



it is not desirable to oxidize to the corresponding tricarboxylic acids, especially when small amounts are involved, because these carboxylic acids are relatively hard to purify, their melting points are high, and the melting points of the isomers are in some cases fairly close together. Hence, we sought a method by which it would be possible to oxidize the oxygenated side chain of the mandelic acids to a carboxyl group without effecting the alkyl groups. These alkyl-substituted benzoic acids are in general easy to purify and have satisfactory melting points for identification purposes.

The basis of the method devised to effect the above purpose is the relative ease with which the oxygenated side chain in these compounds is changed to a carboxyl group. It was found that, when a weighed amount of the mandelic acid was dissolved in dilute alkali and just sufficient potassium permanganate was added to oxidize the oxygenated side chain, the alkyl groups were not affected. The method has been applied to eight substituted mandelic acids to prove its general nature.

Although the use of potassium permanganate to oxidize alkyl benzenes is well known, a careful search of the literature failed to reveal an application to this case.

Experimental

Inasmuch as the procedure was the same in each case, only one example will be described in detail. One gram of 2,4-dimethyl mandelic acid was placed in 125 cc. of water, and 4 cc. of 10% sodium hydroxide was added. This mixture was warmed on a steam bath, and 0.59 g. of potassium permanganate dissolved in 40 cc. of water was added dropwise until the addition of a few drops of the permanganate solution left the solution permanently pink. The reaction proceeded very rapidly. This required practically all the 0.59 g. of permanganate. The excess of permanganate was destroyed with a few drops of sodium bisulphite solution, the manganese dioxide filtered, and the filtrate acidified with hydrochloric acid. A white precipitate formed, which upon crystallization melted at 126-126.5°C., which is the melting point of 2,4-dimethyl benzoic acid.

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[1] Riebsomer, Irvine, and Andrews, 1938. Proc. Indiana Acad. Sci., 47, 139.

[2] Riebsomer, Irvine, and Andrews, 1938. Journ. Amer. Chem. Soc., 60, 1015.

[3] Mulliken, 1914. Identification of pure organic compounds. 1, 85. John Wiley, New York.

Table I presents a summary of the data, including the mandelic acids oxidized, the melting points of the oxidation products, and the melting points of the corresponding benzoic acids as reported in the literature.

TABLE I.

Mandelic Acid oxidized	M.p. of Oxidation product °C	Benzoic Acids	M.p. of benzoic acids—reported in literature °C
p-Methyl	176-177	p-Methyl	178-179
p-Ethyl	112-113	p-Ethyl	112-113
p-n-Propyl	141-142	p-n-Propyl	140-141
p-t Butyl	162.5-164	p-t-Butyl	164
p-t-Amyl	158-158.5	p-t-Amyl	158
2,4, Dimethyl	126-126.5	2,4, Dimethyl	126-127
2,5, Dimethyl	131.5-132	2,5, Dimethyl	132
3,4, Dimethyl	163.5-164	3,4, Dimethyl	163

The authors are glad to acknowledge that a part of this work is the result of a grant made to our Department of Chemistry through its head, Dr. W. M. Blanchard, by the Indiana Academy of Science, at its meeting in the spring of 1938.

Summary

An oxidation method to prove the structures of substituted mandelic acids has been presented and eight examples given.

Chemiluminescent Decomposition Products of Citric Acid

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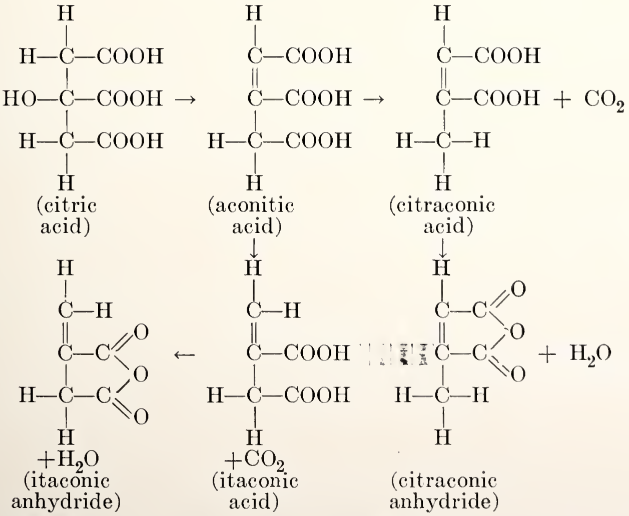
Introduction

There are a number of compounds which are not chemiluminescent themselves, but which, upon fusion and at high temperatures, yield decomposition products which are chemiluminescent upon oxidation. Among these may be mentioned glucose, sucrose, levulose, lactose, tartaric acid, galactose, malic acid, lactic acid, dextrin, potato starch, gum arabic, allantoin, alloxan, uracil, creatine, and citric acid. The citric acid yielded decomposition products which far surpassed all the others in the brilliance of their chemiluminescence. The writers have therefore attempted the separation and isolation of the various decomposition products of citric acid and have studied their chemiluminescent properties.

Discussion

Citric acid breaks down at 105°-120° to form aconitic acid, which in turn breaks down to produce citraconic acid, citraconic anhydride, itaconic acid, and itaconic anhydride. Using a supply of C. P. citric acid and following the method described by Shriner, Ford, and Roll[1], the writers succeeded in isolating all of the above compounds with the exception of the aconitic acid. There remained in the distillation flask, after driving off the above products, a dark brown residue of unknown composition. The reaction may be represented thus:



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[1] Shriner, Ford, and Roll. Organic syntheses. **2**, 23.

Melting points and boiling points of these products were determined as shown in Table I.

TABLE I.

Name	Melting Point	Boiling Point
Citraconic acid..................	68°-69°*	....
Citraconic anhydride............	10°	83° at 7 mm pressure
Itaconic acid....................	157°	....
Itaconic anhydride..............	69°-72°	95°-100° at 1 cm pressure

*This one melting point seems to be quite out of line with the accepted values. However, we note a considerable discrepancy between authorities. Organic Syntheses records this melting point as 92°-93° ; Kamm and the Handbook of Chemistry and Physics place it at 80°.

Of the above list of compounds which were isolated, citraconic anhydride was the only one which exhibited chemiluminescence. This luminescence was much brighter in dilute solution than in those of greater concentration, the optimum being at about 0.11 M. Either alcohol or acetone may be used as the solvent. The oxidizing agents used in this work were a combination of sodium hypochlorite and hydrogen peroxide in alkaline solution. This procedure has been described in a previous article[2].

The dark brown residue which remains in the distilling flask after the decomposition reaction is soluble both in alcohol and water, producing a brown solution. This is strongly luminescent when oxidized. It undoubtedly contains some complex condensation product which is responsible for this action. An attempt was made to remove the brown color from the solution by filtering it with animal charcoal. The color was adsorbed, but with it was removed the light giving substance also.

Summary

1. When citric acid is fused and heated to a high temperature, decomposition products result which are strongly chemiluminescent when properly oxidized.
2. Several of these decomposition products were isolated and tested for chemiluminescence.
3. Citraconic anhydride was found to be luminescent, optimum results being obtained from a 0.11 M solution.
4. Other light-giving substances of unknown composition are present in the dark brown residue from the citric acid decomposition.

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[2] Cottman, Moffett, and Moffett, 1938. Proc. Indiana Acad. Sci., 47, 124-129.

Adsorption of Pancreatic Enzymes[1]

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One of the first experiments on the adsorption of enzymes is described by Vogel (1). In these experiments, an albuminous precipitate was produced by the addition of lead acetate to a solution of pepsin. The precipitate possessed the property of adsorbing pepsin, which could be removed by treatment with hydrogen sulfide and water. The adsorption of pepsin by small particles of calcium phosphate, sulphur, and cholesterol is reported by Burke (2). The separation of the three enzymes of the pancreatic juice has been effected by adsorption methods of Danilewsky (3). In a similar manner, Cohnheim (4) has studied the adsorption of salivary and pancreatic amylase.

Adsorption technique in the separation of enzymes gained considerable impetus through the investigations of Michaelis (5) and Michaelis and Ehrenreich (6), in which adsorbents possessing charges opposite to those of the adsorbates were employed. The adsorption of the enzymes was therefore regarded as a result of the opposite electrical charges of the adsorbate and the adsorbent. Thus it was established "that all substances adsorbable by kaolin must be bases, and all substances adsorbable by alumina must be acids." This conception afforded a criterion for the separation of the enzymes mentioned on the basis of their electrochemical natures (7). Willstätter (8) states that these results apply only to crude enzyme solutions which contain varying amounts of foreign substances. From this investigation and others (9, 10), Willstätter concludes that the nature of the charge of the adsorbent does not necessarily define the nature of the enzyme which is adsorbed, but that the nature of the foreign substance accompanying the enzyme is a controlling factor in the adsorption of specific enzymes by certain adsorbents. Accordingly, an enzyme is considered to consist of an active catalyst and an inert carrier which is colloidal in nature. The carrier is considered to be a substance of high molecular weight, a protein or carbohydrate, and can be separated from the active enzyme and be replaced by another suitable carrier. This so-called carrier theory of the behavior of enzymes with respect to their separation by adsorption methods is substantiated by investigations reported by Fodor (11). According to recent investigations by Dyckerhof and Tawes (12) and Waldschmidt-Leitz and Kofranyl (13), the carrier of pepsin can be replaced by other proteins. Tauber and Kleiner (14), however, point out that the protein carrier of rennin cannot be exchanged for another. Northrup (15) and Sumner (16) show that the decrease in peptic activity is determined by the adsorption of pepsin protein.

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[1] This paper is constructed from a dissertation by James Henry Young to the faculty of the Graduate School of Indiana University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Chemistry.

The protein nature of enzymes has been indicated by the work of Tauber and Kleiner (18, 19), in which it was found that rennin was digested with trypsin and pepsin, pepsin with trypsin, trypsin with pepsin, and salivary amylase with trypsin and papain. It was also found by Falk (20) that lipase is digested with trypsin.

The hydrogen-ion activity of the solution of the enzyme substrate affects the adsorption of the enzyme. It is found that the most efficient adsorption, with the least destruction of the enzyme, is at a specific pH value for each enzyme. The factors upon which the pH optimum depends are: the nature of the enzyme preparation, the rate of hydrolysis of the enzyme (21), the nature of the buffer employed to regulate the pH, and the nature of the substrate. The optimum pH for the digestion of olive oil substrate with lipase in the presence of ammonia-ammonium chloride buffer is 9.2, and for the digestion of trybutyrin substrate with lipsase under the same conditions it is 8.3 (22). According to Kunitz and Northrop (23), the optimum for digestion of casein with purified trypsin is 8 to 9, while crude trypsin will digest casein at a pH of about 7.8. The pH for the adsorption of pancreatic amylase is optimum at about 7.2 (24).

In an effort to isolate a pure enzyme, Willstätter and his associates (25) succeeded in preparing very active concentrates of enzymes brought about by preferential adsorption followed by elution to free the adsorbed enzyme from the adsorbent. The maximum adsorption generally occurred at a definite hydrogen-ion activity and the most efficient elution at another. By this technique, these investigators succeeded in splitting some enzyme complexes into their components.

The purpose of this investigation was to study the adsorption of the enzymes, lipase, trypsin, and amylase, from solutions prepared from desiccated pancreatic extract. From these studies it was possible to prescribe an adsorption treatment for this mixture so that any two of the enzymes could be removed by adsorption on certain adsorbents, leaving any one of the enzymes in the "mother liquor" free from the other two. The behavior of the enzyme so isolated was then studied and compared with its behavior before treatment, that is, in the presence of the other two enzymes.

Proper adjustment of this pH, temperature control, and the use of solutions of bile salts in the digestion mixture were employed to furnish a more nearly natural environment.

Experimental

Materials.—The source of enzymes was desiccated pancreatic extract which contained the three enzymes, lipase, trypsin, and amylase. Pancreatic extracts were the Triple Strength Pancreatin furnished through the courtesy of the Eli Lilly and Company of Indianapolis and Armour and Company of Chicago. Both of these materials gave comparable results.

The adsorbents and their sources or methods of preparation were as follows:

Aluminum oxide on asbestos support was prepared by adding 250 ml. of 3 molar ammonium hydroxide to 250 ml. of aluminum sulfate in the presence of 10 g. of asbestos fiber. The hydrous aluminum oxide was thus precipitated on the asbestos fiber. This mass was dried at 100°C. and activated at 200°C. for 24 hours.

Hydrous aluminum oxide gel was prepared in the same manner as the above, but in the absence of the asbestos fiber. The gel was dried and activated at 250°C.

Lloyd's Reagent was obtained from E. H. Sargent and Company of Chicago, Illinois.

Animal charcoal was purchased from Diagger and Company, Chicago, Illinois.

Silica gel was grade 150-F-1000-3060, obtained from the Davison Chemical Corporation, Silica Gel Division, Baltimore, Maryland.

Cholesterol was obtained from the Pfanstiehl Chemical Company, Waukegan, Illinois.

Carborundum was supplied by the Carbon and Carbide Corporation, Niagara Falls, New York.

Permutite was purchased from the Chicago Apparatus Company, Chicago, Illinois.

Bone charcoal was purchased from the Diagger and Company, Chicago, Illinois.

Magnesium silicate was made by diluting sodium silicate with distilled water to a specific gravity of 1.06 and adding a molar solution of magnesium chloride to the silicate as long as the precipitation occurred. The precipitate was washed free of chlorides, dried in an oven at 100°C., and activated at 200°C. for 24 hours.

Graphite, the fine flaky grade, was purchased from the Chicago Apparatus Company, Chicago, Illinois.

Clay (bauxite) was prepared by activating bauxite at 200°C. for 24 hours. The bauxite was obtained from the Chicago Apparatus Company, Chicago, Illinois.

Kaolin (colloidal) was obtained from Merck and Company, Rahway, New Jersey.

Palladium black was bought from E. H. Sargent and Company, Chicago, Illinois.

The *egg albumen* used was an imported product from China.

Coconut charcoal was obtained from Eimer and Amend Company, New York.

Ferric oxide was obtained from the Chicago Apparatus Company, Chicago, Illinois.

Activated alumina was grade A., 14-20 mesh from the Alcoa Ore Company, East St. Louis, Illinois.

Blood charcoal was bought from Diagger and Company, Chicago, Illinois.

Pumice stone was prepared by treating with concentrated hydrochloric acid, washing with water, and activating for 4 hours at 250°C.

Hydrous aluminum oxide gel in alcohol was prepared in the same manner as the hydrous aluminum oxide gel mentioned above. Alcohol was added at the time of adsorption.

Procedure.—The technique for the adsorption of the enzymes was as follows: Ten grams of the triple strength pancreatin was suspended in 500 ml. of distilled water, to which had been added sodium carbonate and hydrochloric acid to produce a pH of 7.4. The mixture was allowed to stand for 12 hours and then centrifuged for 20 minutes at 2,000 r.p.m. To 100 ml. of the solution after centrifugation was added 10 g. of an adsorbent and the mixture was incubated at 37°C. for 24 hours. The mixture was then centrifuged for 20 minutes at 2,000 r.p.m., and the clear solution was used for determining the enzyme or enzymes that were removed by the adsorbent. A negative test for an enzyme in this clear solution was taken as the indication that it had been removed by the adsorbent.

Tests for lipase were made with olive oil as the substrate in the following manner: To 2 ml. of olive oil was added 15 ml. of the solution after treatment with the adsorbent and the mixture adjusted to a pH of 8 and incubated at 37°C. for 24 hours. The presence of lipolytic activity was indicated by the production of fatty acids as measured by 0.1 N. potassium hydroxide solution required to adjust the pH back to 8.

The presence of amylase in the enzyme solutions after treatment with the adsorbents was detected with the use of starch as the substrate. Five ml. of the solution was added to 10 ml. of a 1% starch solution, and the mixture was adjusted to a pH of 7.2 and incubated at 37°C. for 24 hours. Amylase activity was indicated by tests with iodine, fuchsin, and Fehling's solution which detected the presence or absence of hydrolytic products of the starch.

A solution of casein in normal sodium acetate solution was used as the substrate in the detection of trypsin. Two ml. of the enzyme solution, after treatment with the adsorbents, was added to 10 ml. of the casein solution and the mixture adjusted to a pH of 8 and incubated at 37°C. for 6 hours. The absence of trypsin in the solution was indicated by the production of a white precipitate upon the addition of a few drops of acetic acid.

In order to improve the tests for the three enzymes in the solutions, a few drops of bile salt were added to the digestion mixtures. The bile salt produced a more natural environment for the enzymes and, as a result, increased their respective activities. This proved especially valuable in the lipase tests.

Data and Results.—The data in Table I show the adsorption of the enzymes by the various adsorbents studied. The enzyme adsorbed is indicated by the minus sign (—), which indicates that the enzyme was not present in the solution remaining after treatment with the adsorbent. A positive sign (+) signifies the presence of hydrolytic products in the substrate and indicates that the enzyme was not removed by treatment with the adsorbent.

In general, it is noticed that the aluminum-containing adsorbents manifest a selective adsorbtive capacity for lipase and trypsin. Likewise, the silica containing adsorbents and egg albumen, blood charcoal, and bone charcoal seem to adsorb amylase preferentially.

In Table II the adsorbents are listed according to their abilities to adsorb each of the three enzymes studied. From the table it may be seen that lipase and trypsin are adsorbed by the aluminum- and the silica-bearing compounds more readily than by any of the other adsorbents. Amylase is best adsorbed by the charcoals and egg albumen.

By virtue of the selective adsorption of the enzymes in pancreatin by the adsorbents studied, it is possible to choose certain adsorbents and devise a technique by means of which a complete separation of the three enzymes may be effected. By this means, the mixture of the three enzymes may be treated in such a manner that the solution remaining after treatment will contain only one of the active enzymes.

TABLE I.—Removal of Enzymes from Pancreatin with Various Adsorbents

Adsorbent	Enzymes		
	Lipase	Trypsin	Amylase
$Al(OH)_3$ gel in alcohol	—	—	+
$Al(OH)_3$ gel	—	—	+
Al_2O_3 on asbestos	—	—	+
Activated alumina	—	—	+
Bauxite	—	—	+
Kaolin	—	—	+
Silica gel	—	+	+
Lloyd's Reagent	—	—	+
Magnesium silicate	+	—	—
Permutite	+	—	+
Soapstone	—	+	—
Carborundum	+	—	+
Pumice	+	—	+
Palladium black	—	+	+
Animal charcoal	—	+	+
Blood charcoal	—	+	—
Bone charcoal	—	+	—
Cocoanut charcoal	—	+	+
Graphite	—	+	+
Cholesterol	—	+	+
Egg albumin	+	—	1

+, presence of the enzyme after the mixture has been treated with the adsorbent.

—, absence of the enzyme after the mixture has been treated with the adsorbent.

TABLE II.—The Adsorbents Which Adsorb Each Enzyme

Enzyme Adsorbed	Adsorbent
Lipase*	$Al(OH)_3$ gel in alcohol $Al(OH)_3$ gel Al_2O_3 on asbestos Activated alumina Bauxite Kaolin Silica gel Lloyd's Reagent Soapstone Palladium black Animal charcoal Blood charcoal Bone charcoal Cocoanut charcoal Graphite Cholesterol
Trypsin	$Al(OH)_3$ gel in alcohol $Al(OH)_3$ gel Al_2O_3 on asbestos Activated alumina Bauxite Kaolin Lloyd's Reagent Magnesium silicate Permutite Carborundum Pumice
Amylase	Magnesium silicate Soapstone Blood charcoal Bone charcoal Egg albumin

*No assay showing the quantity of lipase present in the triple strength pancreatin was available. The experiments of this investigation indicated a low content of lipase which probably accounts for the fact that so many adsorbents were found to leave the mixture free from lipase.

Table III indicates the conditions required to carry out this concentration of a single enzyme. In some instances the first treatment with a given adsorbent will remove one of the enzymes and only part of the second, which makes it necessary to treat the solution a second time with the same adsorbent to remove completely the second enzyme and produce a solution containing only one enzyme.

Table III.—Adsorption Technique which, when Applied to Pancreatin, Will Remove All but One of the Enzymes, Lipase, Trypsin, or Amylase

Adsorption method leaving lipase in solution (pH=6-7.6)

Adsorbent	Enzyme removed	Enzyme remaining
1. Mg-silicate	trypsin, some amylase	some amylase, lipase
2. Mg-silicate	amylase	lipase
1. Permutite	trypsin	amylase, lipase
2. Mg-silicate	amylase	lipase

Adsorption method leaving trypsin in solution (pH=6-7.6)

Adsorbent	Enzyme removed	Enzyme remaining
1. Soapstone	lipase, some amylase	some amylase, trypsin
2. Soapstone	amylase	trypsin
1. Soapstone	lipase, some amylase	some amylase, trypsin
2. Egg albumin	amylase	trypsin
1. Cocoanut charcoal	lipase	amylase, trypsin
2. Egg albumin	amylase	trypsin
1. Cocoanut charcoal	lipase	amylase, trypsin
2. Bone charcoal	amylase	trypsin
1. Blood charcoal	lipase, some amylase	some amylase, trypsin
2. Blood charcoal	amylase	trypsin

Adsorption method leaving amylase in solution (pH=6-7.6)

Adsorbent	Enzyme removed	Enzyme remaining
1. Al_2O_3 on asbestos	lipase, some trypsin	some trypsin, amylase
2. Al_2O_3 on asbestos	trypsin	amylase
1. Bauxite	lipase, some trypsin	some trypsin, amylase
2. Bauxite	trypsin	amylase
1. $Al(OH)_3$ gel	lipase, some trypsin	some trypsin, amylase
2. Permutite	trypsin	amylase

TABLE IV.—Activity of Enzymes of the Pancreatic Mixture Compared with Their Activities after Isolation by means of Adsorption from the Other Enzymes

enzyme	in presence of	in absence of	substrate	enzyme solution (ml)	enzyme potency
Lipase	trypsin amylase		2 ml. olive oil	15	8.5 ml. 0.1 N KOH to neutralize fatty acid after 2 hours digestion
Lipase		trypsin amylase	2 ml. olive oil	15	14.2 ml. 0.1 N KOH to neutralize fatty acid after digestion for 2 hours
Trypsin	lipase amylase		10 ml. casein solution	2	complete digestion in 5 minutes
Trypsin		lipase amylase	10 ml. casein solution	2 2	complete digestion in 1 minute
Amylase	lipase trypsin		10 ml. starch paste	5	complete digestion in 4 minutes
Amylase		lipase trypsin	10 ml. starch paste	5	complete digestion in 0.5 minute

This difficulty may be eliminated by using double the weight of the adsorbent per unit volume of the enzyme solution.

In all instances it was found that the activity of the single enzyme remaining after the treatment of the mixture of the three with the suitable adsorption technique was greater than when it was present in the original mixture of the three enzymes. The data in Table IV indicate the activity of each of the enzymes, lipase, trypsin, and amylase, in the solutions treated with the suitable adsorbents as compared with the activity of the enzymes in the presence of the other two.

Summary

1. The following materials are reported as new adsorbents for certain enzymes: soapstone for lipase and amylase; bauxite for lipase and trypsin; graphite for lipase; carborundum for trypsin; and magnesium silicate for trypsin and amylase.

2. From studies involving adsorption of the enzymes, lipase, amylase, and trypsin, which occur in desiccated pancreatin, it was possible to develop adsorption technique by means of which any two of the enzymes may be removed from the third.

3. The potency of the enzyme thus isolated was found to be much greater than when the enzyme was in the presence of the other two.

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The Preparation of Acetyl Bromide from Acetic Acid and Bromine in the Presence of Red and Yellow Phosphorus

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The use of red phosphorus in the bromination of aliphatic acids is not new. Gal[1] and Hanriot[2] used this method for the preparation of acetyl bromide. Various later workers have used red phosphorus either in catalytic or molar quantities for the preparation of acid bromides, alpha-bromo acids, or alpha-bromo acid bromides.

It was stated by Hell[3] that the presence of small amounts of phosphorus resulted in large amounts of acetyl bromide whereas molar amounts tended to yield mainly bromoacetyl bromide. The mechanism of the reaction as postulated by Zelinsky[4] and Volhard[5] was the complete conversion to the acid bromide followed by alpha bromination. This explanation was abandoned by Hell[6] since it was found that alpha-bromination could occur with catalytic quantities of phosphorus. Later experiments by Ward[7] confirm the earlier conclusion that large quantities of phosphorus favor acid bromide formation.

The yields obtained by the use of bromine and red phosphorus for the preparation of acetyl bromide from glacial acetic are illustrated in Table I.

TABLE I. Illustrative Yields Obtained by the Use of Red Phosphorus and Bromine on Glacial Acetic Acid

No.	Gm. Br.	Gm. p (red)	Gm. AcOH	Temp.	Time	% Yield	Remarks
1*	80	10	60	85	2	12	Stood 24 hours.
2*	100	10	60	95	1	8	Refluxed.
3*	160	4	30	?	?	10	Method of Hanriot.
4	240	33	90	?	?	47	Reported by Gal.**
5†	100	13.7	37.4	?	2½	23	Method of Gal.
6†	100	13.7	37.4	?	2½	38	Method of Gal.
7†	100	13.7	37.4	?	2½	36	Method of Gal.

* Experiment carried out by author.

† Experiment carried by D. Herman on NYA assignment.

** Gal, 1863. Annalen 129, 53.

The successful use of a mixture of red and yellow phosphorus for the preparation of ethyl bromide from ethyl alcohol and bromine[8] suggested the use of a similar mixture for the preparation of acetyl bromide.

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[1] Gal, 1863. Annalen **129**, 53.

[2] Hanriot. Ann. Chimie et Physique (5) **17**, 83.

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Glacial acetic acid was treated with bromine in the presence of varying amounts of red and yellow phosphorus and under differing experimental conditions. The data on these experiments are recorded in Table II.

TABLE II.—Summary of Experiments Conducted Using a Mixture of Red and Yellow Phosphorus

No.	Gm.Br	Gm.P		Gm.AcOH	Temp. °C.	Time	% Yield *	Remarks
		red	yellow					
1	80	5	5	60	below 45	1⅙	35	Stood 22 hrs. after Br addition.
2	85	5	7	60	15-30	1⅚	41	Stood 22 hrs. after Br addition.
3	45	2	4	30	below 25	1½	57	Stood 48 hrs. after Br addition.
4	85	5	6½	60	10-20	3½	64	1st heated to 90°, Br dropped in.
5	80	5	5	60	below 30	1	52	Dist. at once.
6	160	4	5	60	10-20	3¼	32	Br dropped in.
7	100	3	5	60	20-40	2	52	Dist. at once, excess Br.
8	100	2	7	60	30-45	3¼	49	P didn't all react.
9	100	3	6	60	20±	3½	49	1st heated to 45°.
10	100	4	5	60	60±	2	37	No external cooling.
11	80	4	5	60	40-45	2½	53	Refluxed till Br reacted.
12	100	4	5	60	35-50	1¼	63	Refluxed till Br reacted.
13	100	4	5	60	35-45	1	65	Refluxed till Br reacted, (70°).
14	100	4	5	60	150-170	½	59	Refluxed till Br reacted.
15	100	4	5	60	175-190	½?	27	Refluxed till Br reacted.

*% Yields are based on the amount of bromine used assuming the following equation to be correct:

$$4CH_3CO_2H+P+2\frac{1}{2}Br_2=4CH_3COBr+PO(OH)_3+HBr.$$

The following procedure was adopted: Place 60 g. of glacial acetic acid, 5 g. of yellow phosphorus, and 4 g. of red phosphorus in a 250 ml. round-bottom flask. Fit the flask with a thermometer, a reflux condenser and a dropping funnel, the tip of which must extend below the surface of the liquid in the flask. Place 100 g. of bromine in the dropping funnel and introduce it into the reaction mixture at such a rate as to require approximately one hour for the addition. Maintain the temperature at 35-50°C. by occasional shaking and external cooling if necessary. After the addition of bromine is complete, reflux the reaction mixture until the red color due to bromine disappears.

Substitute a Liebig condenser (set for distillation) for the reflux condenser and distil the mixture under anhydrous conditions, collecting everything which comes over below 130°. Redistil the distillate so obtained through a Vigreaux or similar column, making sure that anhydrous conditions obtain. Collect the fraction boiling 74-80°. Yield is 78-80 g., 63-65% of the theoretical.

Summary

1. Experiments were conducted for the preparation of acetyl bromide from glacial acetic acid and bromine in the presence of a mixture of red and yellow phosphorus.

2. A procedure was developed which gives a 63-65% yield as compared with a reported 47% yield obtained by the use of red phosphorus alone.

A Study of the Preparation of the Lower Alkyl Iodides

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The present study of the lower alkyl iodides was undertaken when a literature survey revealed disagreement in the ratio of chemicals, procedure, purification, and storage of these compounds[1]. While the majority of laboratory manuals recommend the use of red phosphorus, iodine, and the proper alcohol, *Organic Syntheses* recommends equal amounts of red and yellow phosphorus, iodine, and the proper alcohol[2]. A series of experiments was conducted to determine the effect of the ratio of red to yellow phosphorus upon the yield of the iodide. Ethyl iodide was prepared in these experiments and the results are indicated in Table I[3].

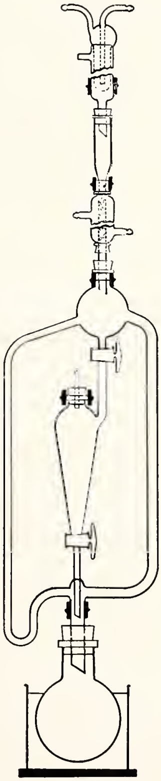

Fig. 1.

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[1] Data collected from laboratory manuals by R. F. Duncan of Purdue University.

[2] Organic Syntheses. 13, 61.

[3] The experimental data listed in this table were obtained by B. J. Freedman under an NYA assignment.

TABLE I.

Run No.	Iodine g.	Alcohol ml.	Phosphorus		Iodide %
			red	yellow	
1	75	90	7.50	0.00	86.5
2	75	90	7.50	0.00	86.0
3	75	90	7.50	0.00	87.0
4	75	90	6.25	1.25	88.1
5	75	90	6.00	1.50	88.7
6	75	90	6.00	1.50	88.3
7	75	90	3.75	3.75	89.5
8	75	90	3.75	3.75	88.2
9	75	90	3.75	3.75	88.8
10	75	90	1.50	6.00	90.2
11	75	90	1.50	6.00	88.0
12	75	90	1.50	6.00	88.5
13	75	90	0.00	7.50	91.0
14	75	90	0.00	7.50	90.5
15	75	90	0.00	7.50	90.0

The results in Table I indicate that the yields of iodide are increased when yellow phosphorus is introduced into the reaction, but these increases do not justify the hazard encountered in handling yellow phosphorus. Furthermore, red phosphorus reacts less violently, and a more controllable reaction ensues.

The apparatus used is a modified type of that recommended in *Organic Syntheses* as indicated in Figure 1. Five hundred fifty milliliters of the absolute alcohol is poured into the reaction flask. This flask is then charged with 50 g. of red phosphorus per pound of iodine to be added. The reaction flask is attached to the apparatus as indicated in Figure 1 and heated with an oil bath until the apparatus is operating under full reflux. The bath temperatures for the respective iodides may be found in Table II. Meanwhile, 100 ml. of the absolute alcohol, followed with 25 g. of iodine, is added to the dropping funnel. When full reflux is attained, the solution in the dropping funnel is introduced dropwise into the reaction flask, and the condensed liquid is allowed to flow into the dropping funnel. As soon as the solution in the dropping funnel is clear or nearly so, another 25 g. of iodine

TABLE II.

Iodide	Boiling Point °C.	Boiling Point of alcohol °C.	Bath Temperature	Addition rate of I_2 min./lb.
Methyl	42.5	64.6	105	62
Ethyl	72.2	78.5	130	62
Isopropyl	89.5	82.5	130–5	63
n-Propyl	102.4	97.2	150–60	61
n-Butyl	131.0	117.7	180–200	70

is placed in the funnel. The average time of addition for the first pound of iodine is listed in Table II. The addition rate is constant above one pound of iodine. (The apparatus is designed to use three pounds of iodine.) The contents of the reaction flask are allowed to reflux until the condensed liquid becomes colorless.

The contents of the reaction flask are distilled from the flask directly into ice water, and the iodide and alcohol are separated by selective solution. Data for this separation may be found in Table III. The iodide is washed several times with water and stored in amber bottles over anhydrous calcium chloride.

TABLE III.

Iodide	Solubility in Water		Yield %
	Iodide	Alcohol	
Methyl	1.4	∞	90
Ethyl	0.4	∞	90–5
Isopropyl	i	∞	95
n-Propyl	i	∞	90–5
n-Butyl	i	8.3	90–5

i = insoluble

Summary

The use of red phosphorus is conducive to a smooth reaction and eliminates the hazards encountered in handling yellow phosphorus. The procedure and apparatus recommended present the advantages gained in handling smaller quantities of reagents, permitting the condensed liquids to return to the reaction flask without encountering the ascending vapors and allowing the iodine to be added more rapidly and in smaller quantities.

The Bromination of Acetone in Non-Aqueous Solutions

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The autocatalytic reaction of acetone with bromine and iodine in non-aqueous solutions has been studied by Dawson[1], by Watson[2], and by Cohen[3]. Preparatory to studies of the catalytic effects of different acids in non-aqueous media, it was decided to repeat some of the previous work which has been done on this reaction and to extend it to include other solvents and mixtures of solvents.

Materials

Acetone. The best obtainable grade of acetone was purified by the method of Shipsey and Werner[4]. Freshly prepared acetone, boiling at 56.15°C. (760 mm.), was used in all determinations. The density, $D_{4^\circ}^{25^\circ}$ was 0.7865.

Ethyl Alcohol. Absolute alcohol was prepared by several refluxings with very active quick-lime and subsequent fractional distillations. Freshly prepared alcohol was used in making all solutions. The boiling point was 78.36°C. (760 mm.) and the density, $D_{4^\circ}^{25^\circ}$, was 0.7852.

Benzene. Thiophene-pure benzene was purified by the method of Peterson and Rodebush[5]. The boiling point of the purified solvent was 80.07°C. (760 mm.).

Carbon Disulphide. After filtering through dry paper, the disulphide was refluxed for three hours over calcined lime. It was then distilled, and the distillate was treated with dry, powdered potassium permanganate (5 g. per liter). After distillation, the product was treated with purified mercury and fractionated twice from phosphorus pentoxide. The boiling point of the purified solvent was 46.10°C. (760 mm.), and the density, $D_{4^\circ}^{25^\circ}$, was 1.2899. It was stored in the dark until ready for use.

Carbon Tetrachloride. The method of purification was the same as that employed by Mills and MacRae[6]. The boiling point of the product was 76.74°C. (760 mm.) and the density, $D_{4^\circ}^{25^\circ}$, was 1.5936 and and $D_{4^\circ}^{0^\circ}$, was 1.63266.

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[1] (a) Dawson and Leslie, Journ. Chem. Soc., **95**, 1860 (1909) ; (b) Dawson, *ibid.*, **99**, 1 (1911) ; (c) Dawson and Powis, *ibid.*, **101**, 1503 (1912).

[2] Watson, *ibid.*, 3065 (1927) ; (b) Hughes and Watson, *ibid*, 1945 (1929).

[3] Cohen, Journ. Am. Chem. Soc., **52**, 2627 (1930).

[4] Shipsey and Werner, Journ. Chem. Soc., **103**, 1255 (1913).

[5] Peterson and Rodebush, Journ. Phy. Chem., **32**, 714 (1928).

[6] Mills and MacRa [illegible] rn. Phy. Chem., **15**, 54 (1911).

Chloroform. The method of Cohen[7] was employed to purify chloroform. The boiling point of the product was 61.15°C. (760 mm.) and the density, $D^{0°}_{4°}$, was 1.5247.

Ethyl Acetate. The method of purification was that described by Wade and Merriam[8]. The boiling point of the purified solvent was 77.20°C. (760 mm.) and the density, $D^{25°}_{4°}$, was 0.8945.

Ethylene Dichloride. This solvent was dried over phosphorus pentoxide for 24 hours and fractionated twice. The middle portion, boiling at 82.95°C. (760 mm.) was used.

Dichloroethyl Ether. The product of the Eastman Kodak Company was first dried with anhydrous calcium chloride, followed by metallic sodium. The dry ether was then distilled, and the middle portion was used. The boiling point was 172.5°C. (739 mm.).

Bromine. Three extractions were made with 10% sodium hydroxide solution. The bromine was then distilled in an all-glass apparatus, once alone, and twice from phosphorus pentoxide. It was stored in an all-glass container from which the bromine was forced into a calibrated tube.

Method

The reaction mixture consisted of 100 ml. of the solvent, 10 ml. of acetone, and 1.0817 g. of bromine, unless otherwise specified. The mixture was placed in a 250 ml. closed volumetric flask which was immersed in an ice bath. Samples (2 ml.) were withdrawn at intervals. These were immediately diluted with an aqueous potassium iodide solution and titrated with 0.05 N sodium thiosulphate solution.

Results and Discussions

The rate of the reaction was found to be independent of the concentration of bromine but to depend upon the concentration of acetone. This is in keeping with the results obtained with aqueous solutions and lends support to the contention that the reaction whose rate is increased is one involving acetone alone. This reaction probably involves the keto-enol transformation, which would then be the reaction that is catalysed by hydrogen bromide. The bromination of the enol modification is assumed to be instantaneous.

The natural rate of the reaction was studied by adding 1.0817 g. of bromine to 110 ml. of acetone. Cohen, using 0.840 g. of bromine and the same quantity of acetone, found that the reaction was complete in approximately 18 minutes. We found it to be complete, i. e., all the bromine was consumed, in 12 minutes and to show a much more pronounced latent period (Table I) than Cohen observed.

In aqueous solution (Table II) the bromine was completely consumed in 67 hours. Here the reaction showed an initially rapid rate

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[7] Cohen, *loc. cit.*

[8] Wade and Merriam, J. Chem. Soc., 101:2429 (1912).

TABLE I.—Rate of the Reaction in Organic Solvents
N/20 Sodium Thiosulfate (ml. used to titrate 2 ml. sample)

Time (Min.)	Pure Acetone	Carbon Disulfide	Ethylene Dichloride	Carbon Tetrachloride	Chloroform	Dichlorodiethyl ether	Ethyl Acetate	Ethyl Acetate +HCl
0	5.30	5.30	5.35	5.30	5.30	5.30	5.05	5.30
1	4.85	4.80	4.90	4.90	4.80			4.90
2	4.80						4.80	4.60
3						5.30		
4	4.80	4.60	4.90	4.90	4.80			1.65
5								1.25
6	4.80							0.20
7		4.50					4.70	0.00
8	4.50					5.25		
9		4.40		4.90	4.80			
10	3.80							
11							4.70	
12	0.00	4.30			4.75			
13			4.85					
14				4.90				
15		1.50	4.70		4.70			
16		0.00					4.70	
17						4.00		
18				4.85	4.60			
20					4.50		4.60	
22			2.70		4.30			
24						1.15	4.50	
25				2.70				
26			0.00		3.00	0.40		
29				0.00				
30					0.20	0.00		
31					0.00			
33							0.40	
35							0.00	

TABLE II.—Reaction in Water

Time		N/20 $Na_2S_2O_3$ (in ml.)
Hours	Minutes	
0	0	5.30
0	1	4.70
0	5	4.60
0	25	4.31
0	40	4.30
1	3	4.30
1	20	4.30
1	56	4.26
4	40	4.20
7	30	4.20
18	45	3.02
22	40	2.60
26	20	2.18
29	30	1.75
42	20	0.80
49	20	0.50
55	20	0.30
67	00	0.00

during the first hours. Suddenly, it practically ceased for a period of approximately six hours; it then became much faster, the rate at which hydrobromic acid was formed increasing with the time. The reaction became slower again after some 40 hours.

Blanks were run for all the organic solvents used in the experiments. Their purpose was to determine whether or not bromine reacts with the solvent to an appreciable extent at 0°C. After six hours, no decrease in the quantity of sodium thiosulphate solution required in the titration could be detected except for alcohol, where a decrease in titre of 0.6 ml. occurred.

TABLE III.—Reaction in Ethyl Alcohol

A.		B.	
Alcohol dried in usual manner (Wt. of Br_2=0.9196 g.)		Intensively dried alcohol (Wt. of Br_2=0.8107 g.)	
Time in Minutes	(ml.) N/20 $Na_2S_2O_3$	Time in Minutes	(ml.) N/20 $Na_2S_2O_3$
0	3.8 ml.	0	3.35 ml.
12	3.00	12	2.35
26	2.65	22	2.10
41	2.30	38	1.70
51	2.10	43	1.30
62	2.00	48	.95
71	1.80	56	.30
91	1.35	61	0.00
103	1.20		
114.5	.70		
117	.60		
121	.60		
126	0.00		

TABLE IV.—Reaction in Benzene

A.		B.	
Benzene dried in usual manner (Wt. of Br_2=1.2342 g.)		Intensively dried benzene (Wt. of Br_2=1.089 g.)	
Time (Minutes)	N/20 Sodium Thiosulfate (ml.)	Time (Minutes)	N/20 Sodium Thiosulfate (ml.)
0	5.10 ml.	0	4.50 ml.
1	4.60	10	2.70
24	4.60	15	2.70
59	4.60	20	2.55
71	4.50	25	2.50
81	2.20	33	0.00
86	0.00		

The results obtained when the course of the reaction was studied in carbon disulfide, ethylene dichloride, carbon tetrachloride, chloroform, ethyl acetate, and dichloroethyl ether are shown in Table I. The ethyl alcohol used as a solvent in the experiments reported in Table IIIA was dried in the manner previously described. The results obtained with this solvent could be reproduced to within 5-6 minutes for the period required for complete consumption of the bromine (about 120 minutes in all). Results for other solvents in which the time for complete reaction was shorter could be reproduced to within one minute. Table IIIB shows the results obtained with ethyl alcohol which had been subjected to prolonged and repeated treatments to remove the water originally present. Tables IVA and IVB show the results obtained by using benzene which had been treated, for widely different periods of time, with phosphoric anhydride.

The results obtained with these solvents differ from those reported by others in the following respects:

(1) Dawson and Leslie report that acetone and iodine react more rapidly in methyl alcohol than in benzene or carbon tetrachloride. This result was unexpected. One should expect the course of the reactions in alcohol to resemble that in water more closely than it does the reaction in carbon disulphide or benzene. According to our results in the reaction between bromine and acetone, ethyl alcohol in the role as solvent shows a greater similarity to water than do carbon tetrachloride and benzene. However, the reaction in alcohol is much faster than in water and becomes still more rapid as the alcohol is more completely dried.

(2) The time required for the utilization of all the bromine in the reaction is much less than the time reported by Cohen. We found, for example, that the reaction was complete in 16 minutes when carbon disulphide was used as solvent, in 29 minutes for carbon tetrachloride, and in 31 minutes for chloroform. Cohen's results for the same solvent, although he used less bromine, are approximately 110, 180, and 130 minutes. We believe that Cohen's results are too high and that they are caused by using acetone or solvents which contained appreciable amounts of water. When we added 0.0258 g. of water to 100 ml. of carbon tetrachloride and the usual quantities of bromine and acetone, we found that the reaction was complete in the same period of time as Cohen reports for anhydrous carbon tetrachloride, 180 minutes. This reaction had a very long latent period (over two hours) and then proceeded rapidly to completion.

The effect of small amounts of water in the solutions is also demonstrated by the results obtained in benzene and alcohol. There can be no doubt concerning the powerfully retarding effect of water upon the reaction. This fact supports the belief that molecular hydrogen bromide and not oxonium ion is the catalyst of the reaction.

(3) Cohen overlooked the latent period in all the reactions which he studied. This has been pointed out by Watson, although the latter does not offer any specific information on the point. It was first observed by Dawson and Leslie, whose results, however, like Cohen's,

indicate that the solvents or the acetone used by them contained water, which always increases the time required for the reaction. Our results show a latent period for the reaction in all organic solvents. In ethyl acetate this period is removed completely by the addition of dry hydrogen chloride.

(4) Except in the instance of benzene as solvent, there is no pronounced initial period of activity for non-aqueous solutions as has been shown to be true for the reaction in water. The initial decrease in the titre corresponds almost exactly in every case to the decrease in the concentration of bromine due to dilution when 10 ml. of acetone is added.

(5) The bromination reaction has a high initial velocity in the intensively dried benzene, which is entirely absent in benzene dried in an ordinary way. This cannot be caused by a catalyst originally present in the benzene since the period of activity at the beginning of the reaction was followed by a period of inactivity. One may venture the suggestion that a considerable quantity of enol acetone is present in intensively dried benzene and that this enolic form is brominated instantaneously.

(6) The addition of 2 ml. of pyridine to the reacting mixture in carbon tetrachloride completely stopped the action of bromine upon acetone (for three hours).

(7) The addition of sodium acetate to the reacting mixture in ethyl alcohol retarded the reaction rate. During the first sixty minutes there was scarcely any reaction, whereas in the absence of the salt more than half of the bromine was consumed in the same length of time. Lithium chloride increased the rate of the reaction in ethyl alcohol.

Action of Ammonia on Hexynyl Magnesium Halides

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It is a well known fact that "acidic" substances decompose Grignard reagents as follows,

$$RMgX + HB \rightarrow RH + MgXB$$

where HB represents water, alcohols, ammonia, primary and secondary amines, etc.

However, the acetylenic Grignard reagents, $RC{\equiv}CMgX$, are related to the acetylides, and acetylides of first and second group metals are stable to ammonia. It was, therefore, thought of some interest to study the action of ammonia on typical acetylenic Grignard reagents. Hexynyl magnesium chloride and bromide were selected for this work. It was thought that ammonia might favor the following transformation,

$$2\ C_4H_9C{\equiv}CMgX \rightarrow (C_4H_9C{\equiv}C)_2Mg + MgX_2$$

rather than ammonolysis. This anticipation was not realized, and ammonia, either liquid or gaseous, was found to decompose the hexynyl magnesium halides, though incompletely. Treatment of ethereal solutions of the hexynyl magnesium halides with ammonia yielded bulky, amorphous, white precipitates. These were filtered, dried, weighed, and analyzed for magnesium, halogen, and ammonia nitrogen. In each instance these data correspond roughly to compositions in accord with the formula,

$$C_4H_9C{\equiv}CMgNH_2 . 2MgX_2 . Mg(NH_2)_2 . 6NH_3$$

The reactions affording such precipitates must be complex. A suggested equation, in accord with experimental observations, is:

$$4\ C_4H_9C{\equiv}CMgX + 9\ NH_3 \rightarrow 3\ C_4H_9C{\equiv}CH + C_4H_9C{\equiv}CMgNH_2 . 2MgX_2 . Mg(NH_2)_2 . 6NH_3$$

Table I presents the experimental data upon which these conclusions are based.

Table I.—Experimental Data: Action of Ammonia on Hexynyl Magnesium Halides.

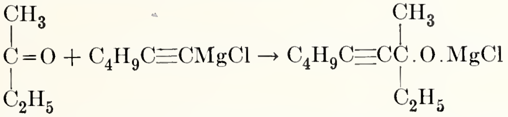
(a) Experiments with $C_4H_9C{\equiv}CMgCl$
Precipitate calculated for $C_4H_9C{\equiv}CMgNH_2 . 2MgCl_2 . Mg(NH_2)_2 . 6NH_3$

Amount $RC{\equiv}CMgCl$ Mols	NH_3 added as	Analyses of Precipitate							
		Wt. Ppt., g.		Calc. (%)			Found (%)		
		Calc.	Found	Mg	Cl	N	Mg	Cl	N
0.5	gas	58.81	61.9	20.68	30.15	26.80	21.81	30.87	27.70
0.5	liqd.	58.81	62.5	20.68	30.15	26.80	16.95	29.00	26.46

(b) Experiments with $C_4H_9C{\equiv}CMgBr$
Precipitate calculated for $C_4H_9C{\equiv}CMgNH_2 . 2MgBr_2 . Mg(NH_2)_2 . 6NH_3$

Amount $RC{\equiv}CMgBr$ Mols	NH_3 added as	Analyses of Precipitate							
		Wt. Ppt., g.		Calc. (%)			Found (%)		
		Calc.	Found	Mg	Br	N	Mg	Br	N
0.5	gas	81.04	86.1	15.01	49.31	19.45	14.09	48.90	19.17
0.5	liqd.	81.04	88.7	15.01	49.31	19.45	14.13	51.09	19.25

That ammonia causes incomplete ammonolysis is shown also by other facts. For example, addition of methyl ethyl ketone, *after ammonia*, gave a 14.3% yield of 3-methyl-4-nonyne-3-ol:



$$\begin{array}{c}CH_3\\|\\C{=}O\\|\\C_2H_5\end{array} + C_4H_9C{\equiv}CMgCl \rightarrow C_4H_9C{\equiv}C\begin{array}{c}CH_3\\|\\C\\|\\C_2H_5\end{array}.O.MgCl$$

In a similar manner, butyl bromide gave an 8% yield of 5-decyne and diethyl sulfate gave a 6.4% yield of 3-octyne. These reactions indicate clearly that the ammonia had decomposed the Grignard reagent incompletely.

Experimental

Materials.—Butyl acetylene was obtained by a modified Picon synthesis[1]. Dry magnesium turnings and ether distilled from phosphorus pentoxide were used in every case.

Action of Liquid Ammonia on Hexynyl Magnesium Chloride.—To one-half mole (12.16 gm.) of magnesium turnings covered with dry ether in a three-liter three-necked flask, equipped with a mercury stirrer and a reflux condenser, was added ethyl chloride through a dropping funnel. The flask was cooled in a water bath, and the stirring was continued during the addition of the ethyl chloride.

Then one-half mole (41.0 gm.) of butyl acetylene in an equal volume of dry ether was added drop-wise to the ether solution of ethyl magnesium chloride. After all the butyl acetylene had been added, the ether solution was refluxed until all the ethane and unreacted ethyl chloride were driven off. After replacing the condenser with a long piece of glass tubing, used as a vent, the flask was cooled in a bath of carbice and acetone. Then 1.5 liters of liquid ammonia was slowly introduced to the reaction flask through the dropping funnel. The addition of liquid ammonia caused a milky-white precipitate to form which had a tendency to cake on the side of the flask unless vigorous stirring was employed.

Stirring was continued for a half hour; then the entire mixture was filtered through a large funnel. The process of filtration required from three to four hours, and even after that time the precipitate was still very pasty. After the liquid ammonia evaporated from the filtrate, the remaining liquid was distilled, and 18.5 gm. of butyl acetylene was recovered.

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[1] Vaughn, Hennion, Vogt, and Nieuwland, 1937. Journ. Org. Chem. 2, 1. Hennion, 1938. Proc. Indiana Acad. Sci., 47, 116.

The precipitate, a pasty white mass, was dried over concentrated sulfuric acid in a vacuum desiccator. Since the acid absorbed so much ammonia, it was necessary to change the acid at least three times before the precipitate reached a constant weight. The final product was a fine, white, flaky powder which obtained a constant weight after one week's drying. This white powder was analyzed for magnesium, chlorine, and nitrogen.

Action of Gaseous Ammonia on Hexynyl Magnesium Chloride.—One-half mole (70 46 gm.) of hexynyl magnesium chloride was prepared in the same manner as described above. At this point the dropping funnel was replaced by a piece of glass tubing extending just above the surface of the liquid. With continual stirring gaseous ammonia was introduced into the reaction flask until no more precipitate was formed. After adding 200 cc. of dry ether the resulting mixture was filtered and treated as described above.

Action of Liquid Ammonia on Hexynyl Magnesium Bromide.—One-half mole (92.68 gm.) of hexynyl magnesium bromide was prepared and treated with liquid ammonia in the same manner as described for the treatment of hexynyl magnesium chloride with liquid ammonia except, of course, that ethyl bromide was used as the starting reagent in place of ethyl chloride.

Action of Gaseous Ammonia on Hexynyl Magnesium Bromide.—This experiment was carried out in a manner similar to that described under the action of gaseous ammonia on hexynyl magnesium chloride. After analyzing this precipitate for magnesium, bromine, and nitrogen, 80 gm. was placed in a two-liter round bottom flask equipped with a reflux condenser. After adding 500 cc. of anhydrous benzene, the mixture was refluxed for one hour in order to extract any free organic matter that might be present in the precipitate. After the mixture was filtered, distillation of the benzene filtrate revealed no dissolved organic matter.

Preparation of 3-methyl-4-nonyne-3-ol.—One-half mole (70.46 gm.) of hexynyl magnesium chloride was prepared by the method described above. After the addition of 1.5 liters of liquid ammonia, the stirring was continued for a short time so as to insure good suspension of the insoluble precipitate. Then one-half mole (36.06 gm.) of methyl ethyl ketone was added slowly to the reaction mixture through the dropping funnel. Stirring was continued until nearly all the liquid ammonia evaporated; then more dry ether was poured into the flask.

The mixture was hydrolyzed with 500 cc. of 10% hydrochloric acid solution. The ether layer was separated, washed with water several times, and then washed with 200 cc. of 20% sodium carbonate solution, washed again with water, and the ether portion dried over anhydrous magnesium sulfate. Upon distillation a 14.30% yield of the condensation product, 3-methyl-4-nonyne-3-ol, was obtained.

Preparation of 5-decyne.—A similar procedure was followed for preparing 5-decyne as for the synthesis of 3-methyl-4-nonyne-3-ol, except that one-half mole (68.5 gm.) of butyl bromide was added to the reaction mixture in place of the methyl ethyl ketone. A 7.95% yield of 5-decyne was obtained.

Preparation of 3-octyne.—In preparing 3-octyne the same procedure was followed as given above, except one mole (154.14 gm.) of diethyl sulfate was used, according to the mechanism proposed by Thorn, Hennion, and Nieuwland[2]. A 6.35% yield of 3-octyne was obtained.

Summary

Ammonia has been found to decompose hexynyl magnesium halides incompletely. The products of such reactions are complex amorphous precipitates, insoluble in ether and in liquid ammonia. Hypothetical formulas have been ascribed to these materials: $C_4H_9—C\equiv MgNH_2 2MgX_2 . Mg(NH_2)_2 . 6NH_3$, where X represents Cl or Br.

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[2] Thorn, Hennion, and Nieuwland, 1936. Journ. Am. Chem. Soc., 58, 796.

Molal Boiling Point Constant for Butylacetylene

G. F. Hennion and John Goncher,
University of Notre Dame

Butylacetylene (1-hexyne) constitutes an excellent example of an aliphatic hydrocarbon readily prepared in pure form[1]. As a part of a research program concerning substituted acetylenes it was decided to determine the molal elevation of the boiling point for butylacetylene. The data have revealed that neither the triple linkage nor the labile hydrogen cause undesirable effects in the cases studied.

Six solutes were selected for the experiments. Each was of Eastman grade. The butylacetylene was prepared as previously described[1]. The McCoy apparatus was used with a Beckman thermometer. The essential data are given in Table I. For the sake of simplicity, the volume of each solution was considered to be the volume of the solvent. The density was taken as 0.7108. The constants (K_b) given are, therefore, close approximations only and are expressed as degrees per mole of solute in 1000 grams of solvent. The values were calculated from the expression

$$K_b = \frac{m(\Delta t)G}{1000\ g}, \text{ where}$$

K_b = B. p. constant
m = mol. wt. of solute used
G = wt. of solvent used
g = wt. of solute used.

Independent work in this laboratory[2] on the vapor pressures of acetylenes has shown that butylacetylene has a molal heat of vaporization of about 7586 calories at its normal boiling point, 71°. This value permits calculation of the boiling point constant by means of the equation

$$K_b = \frac{R(T_1)^2}{L_v n_1}, \text{ where}$$

R = gas constant
T_1 = b. p. of solvent in degrees Kelvin
L_v = molar heat of vaporization
n_1 = moles of solvent per kilogram

Substituting,

$$K_b = \frac{1.985(71+273)^2}{7586(1000/82)} = 2.54°$$

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[1] Hennion, 1937. Proc. Indiana Acad. Sci., **47**: 116-121.

[2] Rich and Hennion, Unpublished work, this Laboratory.

The calculated value, 2.54°, is only in fair agreement with the experimental average, and no value as high as 2.54° was ever found.

TABLE I.—Molal Boiling Point Constant Data for Butylacetylene

Solute	Grams Solute	Grams Solvent	Δt	K_b
p-Dibromobenzene	0.2500	14.9	0.145	2.04
(M.W., 235.9)	0.4000	21.2	0.160	2.01
	0.5000	24.9	0.175	2.05
Diphenyl	0.3019	17.4	0.260	2.31
(M.W., 154.1)	0.4038	11.7	0.540	2.42
	0.6438	18.1	0.520	2.26
Naphthalene	0.3002	13.1	0.390	2.19
(M.W., 128.1)	0.6002	18.5	0.550	2.17
	0.2008	12.8	0.370	2.22
m-Dinitrobenzene	0.3000	12.4	0.315	2.19
(M.W., 168)	0.4000	19.9	0.270	2.26
	0.5000	22.4	0.290	2.18
Benzophenone	0.3000	12.8	0.285	2.26
(M.W., 182.1)	0.4000	15.3	0.310	2.16
	0.5000	20.3	0.290	2.14
Stilbene	0.2006	11.4	0.230	2.36
(M.W., 180.1)	0.3012	22.0	0.180	2.38
	0.4000	12.4	0.410	2.30
Average value of K_b				2.21

Summary

1. Butylacetylene is an aliphatic hydrocarbon readily prepared in pure form and entirely suitable for many molecular weight determinations by the boiling point method.

2. Experimental values for the molal boiling point constant for butylacetylene indicate a value of about 2.21° per mole of solute in 1000 grams of solvent.

Nitration of Saturated Hydrocarbons

H. B. Hass,
Purdue University

Although nitroparaffins were first produced by Victor Meyer[1] in 1872 by the metathesis of alkyl iodides and silver nitrite it was eight years later that Beilstein and Kurbatov[2] first nitrated a paraffin. They were investigating the nature of an American petroleum, and, having previously shown that naphthenes (cycloparaffins) could be nitrated, they treated with nitric acid a fraction boiling in the region of heptane. In this way they were able to isolate pure normal heptane, but they also obtained a product boiling at 196-200°C. which was a mixture of mononitroheptanes.

Since the nitration of aromatic hydrocarbons had proved to be a preparative tool of the first importance, it is not surprising that a number of investigators took up the study of the analagous reactions of the alkanes. Francis and Young, Markovnikov, Konovalov, Nametkin, Worstall, Buc and Hopkins, and Poni and Costachescu are some of the workers who took part in these researches. The paraffins nitrated ranged from isopentane to dodecanes; a number of cycloparaffins and also the aliphatic side-chains of aromatic hydrocarbons were found to be capable of the same reaction. A number of patents[3] describe the nitration of high-boiling petroleum distillates. The constitution of the hydrocarbons comprising these products is still completely unknown so that it is not easy to ascertain to what extent these workers were dealing with nitration of aromatic, olefinic or saturated hydrocarbons.

Results obtained in the liquid-phase nitration of saturated hydrocarbons at temperatures from 20° to the boiling point of nitric acid showed that the ones most readily attacked were those containing a cyclic tertiary carbon atom; these were followed by those with an acyclic tertiary carbon atom and finally by the naphthenes and paraffins free from tertiary carbon atoms. In general, the nitroparaffins obtained contained the same number of carbon atoms as the hydrocarbon nitrated, although Beilstein and Kurbatov[4] isolated a dinitroisobutane from the nitration products of a petroleum fraction boiling from 40°-50°C., which was presumably free from isobutane (b.p. -10.2°C.). The reaction showed a marked selectivity for the substitution of tertiary and secondary hydrogen atoms, in many cases producing substantially only one of the isomeric nitroparaffins theoretically derivable from a given alkane. When isobutane was nitrated in this laboratory in vapor phase at a temperature of 150°C., the product was tertiary nitrobutane of 99%

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[1] Meyer, 1872. Ber. 5:203-5, 399.

[2] Beilstein and Kurbatov, 1880. Ber. **13**:1818.

[3] Ellis. The chemistry of petroleum derivatives. 1:1052-4.

[4] Beilstein and Kurbatov, 1881. Ber. **14**:1620.

purity; the reaction under these conditions behaving as if it were in the liquid phase.

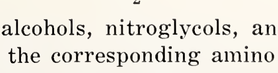
At higher temperatures, however, the vapor-phase reaction gives results quite different from those obtainable under the conditions previously described. Thus n-pentane[5], upon nitration at 400°C., yields all three of the simple substitution products, i.e., 1-nitropentane, 2-nitropentane and 3-nitropentane, but also nitromethane, nitroethane, 1-nitropropane, and 1-nitrobutane. These results are in harmony with those obtained upon every paraffin whose vapor-phase nitration at high temperature has been carefully studied. Every mononitroparaffin is obtained which is theoretically derivable by adding a nitro group to the free radicals obtainable from a given hydrocarbon by fission of a C-H or a C-C bond. Whether or not free radicals are actually involved in the nitration is still not finally decided, but the perfect accuracy of the free-radical mechanism in predicting the identity of the nitro-paraffins obtained lends it an air of probability.

From the viewpoint of the synthetic organic chemist, the ready availability of the primary and secondary nitroparaffins is of interest because of the variety of chemical reactions which these substances will undergo. Thus primary nitroparaffins are hydrolyzed in the presence of strong mineral acids to form first hydroxamic acids and then the carboxylic acids having the same number of carbon atoms as the nitroparaffin used. If desired, the reaction may be stopped at the hydroxamic acid stage. This reaction promises to make hydroxylamine more readily available for large-scale syntheses than has been true in the past.

Both primary and secondary nitroparaffins undergo condensations of the aldol type when allowed to add aldehydes in the presence of a mild base. An illustration of this reaction is the following:

$$CH_3NO_2 \xrightarrow{HCHO} CH_2OH{\cdot}CH_2NO_2 \xrightarrow{HCHO} (CH_2OH)_2\,CHNO_2 \xrightarrow{HCHO} (CH_2OH)_3CNO_2.$$

When formaldehyde is used for the reaction, all of the hydrogen atoms attached to the carbon atom holding the nitro group can take part in the condensation. This is also generally true when nitromethane is used regardless of the aldehyde. When nitroparaffins of two or more carbon atoms are condensed with aldehydes of similar complexity, only one molecule of aldehyde reacts per molecule of nitroparaffin. Compounds can be produced, however, of the following type by successive condensations, using formaldehyde and one of its homologs:



$$R{\cdot}CHOH{\cdot}\underset{\displaystyle NO_2}{\underset{|}{C}}(R')\,CH_2OH.$$

Nitroparaffins, nitroalcohols, nitroglycols, and nitroalkanetriols can all be reduced readily to the corresponding amino compounds. The properties of the hydroxyamines thus obtained are suggestive of those of triethanolamine. They may also be converted to the esters of organic or of inorganic acids. Thus nitration of 2-hydroxymethyl-2-nitro-1,3-propanediol in the usual way with mixed acid yields the trinitrate which is a powerful high explosive.

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[5] Hass and Patterson, 1938. Ind. Eng. Chem. 30:67.

Chlorination of nitroparaffins in the presence of a base yields chloronitroparaffins in which the chlorine replaces one or more of the hydrogen atoms attached to the carbon atom holding the nitro group. For example, the chlorination of nitromethane yields chloropicrin which, while no longer of military importance as a toxic vapor, is of distinct value as an insecticide.

Nef[6] showed that the sodium salt of a nitroparaffin would, upon acidification with sulfuric acid under the proper conditions, yield an aldehyde or ketone depending upon whether it is derived from a primary or secondary nitro derivative.

$$2\cdot R\ CH{=}NO_2\cdot Na + H_2SO_4 \rightarrow Na_2SO_4 + 2\ RCHO + N_2O + H_2O$$

The nitration reaction therefore offers an easy means of converting saturated hydrocarbons to the following classes of substances: nitroparaffins, amines, hydroxamic acids, carboxylic acids, hydroxylamine and its derivatives (such as oximes), nitroalcohols, nitroglycols, nitroalkanetriols, aminoalcohols, aminoglycols, aminoalkanetriols, the esters of the preceding six classes derived from either organic or inorganic acids (including certain high explosives), and the substituted amides derived from any of the amino derivatives, chloronitroparaffins, aldehydes, and ketones. The exploration of this wide field of synthesis is a fascinating research topic for a number of the members of the Department of Chemistry at Purdue.

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[6] Nef, 1894. Ann. 280:263-91.

Iodine Number of Oil of Peppermint

LAWRENCE H. BALDINGER, University of Notre Dame

Introduction

In the analysis of essential or volatile oils, little or no importance is attached to the determination of the iodine number, inasmuch as other chemical constants for these oils seem to be of more importance in establishing standards of purity and identity. The decoloration of an iodine in chloroform solution by a sample of oil of peppermint in a chance qualitative test suggested the problem of the determination of the iodine values for several samples of this essential oil as a possible aid in determining the purity and commercial value of the oil.

The usual chemical constants which are determined for oil of peppermint include the ester value, expressed as menthyl acetate, total menthol content, free and combined in the form of menthyl acetate, and the menthone content. The United States Pharmacopoeia[1] sets standards for the first two values, requiring not less than 5% of esters, expressed as menthyl acetate ($C_{10}H_{19}.C_2H_3O_2$), and not less than 50% total menthol ($C_{10}H_{19}.OH$), free and as esters, but specifies no purity rubric for menthone content. Arbitrary values for this substance have been suggested by the large-scale users of this essential oil since it is believed that some of the characteristic odor and flavor of peppermint oil is due to the menthone ($C_{10}H_{18}O$).

Inasmuch as chemical and physical constants had been determined for a number of samples of peppermint oil, it seemed desirable to calculate the possible relationships between the iodine values and the other constants for these oils. While it must be admitted that these relationships are usually of theoretical interest only, it frequently happens that practical ratios do exist between various constants.

Experimental Procedure

For the determination of the iodine values of the oils, a method suggested by F. W. Rosenmund and W. Ruhnhenn[2] was used, a method similar to but faster than the Hanus procedure. Strictly speaking, because of the substitution of bromine for iodine in the reagent, the value might be considered as a bromine value, except for the fact that the milli-equivalent for iodine instead of bromine is used in the calculations.

The reagent is prepared by mixing 8 g. of pyridine and 10 g. of concentrated sulfuric acid with 20 ml. of glacial acetic acid, and to this solution adding 12 g. of bromine in 20 ml. of glacial acetic acid. After thorough mixing, the solution is diluted to one liter with glacial acetic acid.

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[1] The United States Pharmacopoeia, 11th. Dec. Rev., Mack Printing Co., 1936, p. 259.

[2] Rosenmund and Ruhnhenn. Pharm. Weekblad. 61:76 (1924); through Year Book of the American Pharmaceutical Association 13:428 (1924).

To determine the iodine number for a sample, 0.5 ml. of oil, accurately weighed, is treated with 25 ml. of the reagent and allowed to stand for 30 minutes. Two grams of potassium iodide is then added and the mixture is diluted with 50 ml. of water. The mixture is allowed to stand for 10 minutes and the iodine liberated by the excess bromine is titrated with N/10 sodium thiosulfate solution. With each group of samples a blank is run under similar conditions. The iodine value is calculated using the following formula:

$$\text{Iodine Value} = \frac{(B - A)(0.01269)100}{W}$$

where *B* is the number of milliliters of N/10 sodium thiosulfate solution required for the blank, *A* is the number of milliliters of N/10 sodium thiosulfate solution for back titration, 0.01269 is the iodine factor for N/10 iodine solution, *W* is the weight of sample. No marked variation of iodine values with length of exposure of oils to the bromine solution was observed (Table I).

The menthol and ester values were determined using the methods of the United States Pharmacopoeia.[3] The menthone values were determined, using hydroxylamine hydrochloride in a method formulated from a number of references[4]. The chemical constants are tabulated in Table II. In Table III ratios between the iodine values and the other chemical constants are listed.

Discussion and Summary

The results of the investigation indicate that the iodine number may be of theoretical interest in the examination of peppermint oil samples. Data for a larger number of samples, however, is necessary before the practicability of this constant can be demonstrated. From the data as listed in Table II it will be observed that those oils with high iodine

TABLE I.—Variation of Iodine Values with Length of Exposure of Oil to Bromine Solution

Weight of Oil	Time in Minutes	Iodine Value
0.4470	10	65.7
0.4410	10	66.0
0.4812	15	65.8
0.4401	15	66.4
0.4812	20	66.6
0.3442	20	67.1
0.4771	25	66.6
0.3412	25	67.3
0.3440	30	67.1
0.3414	30	67.2

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[3] The United States Pharmacopoeia, 11th. Dec. Rev., Mack Printing Co., 1936, p. 259.

[4] Schimmel Report, **1928**:22, 23; **1929**:143; **1932**:104; **1933**:12, 92.

values have low menthol and high menthone contents, whereas those samples with normal menthol and menthone contents have iodine values which vary between 62 and 72. The ratio of the iodine value to the combined ester and menthone values for the latter samples is practically constant, while the samples with low menthol and high menthone values show a slightly lower ratio than the normal samples. With additional data from a large number of samples of all grades it may be possible to propose a range for the iodine value as an aid in establishing the quality of peppermint oil. The investigation is being continued using other iodinating solutions.

TABLE II.—Chemical Constants for Peppermint Oil Samples

Sample Number	Ester %	Menthol %	Menthone %	Iodine Value
1	6.43	53.60	24.32	62.5
2	5.46	52.50	26.86	67.5
3	5.41	50.94	27.47	68.1
4	6.36	52.76	24.98	66.1
5	5.76	49.35	26.77	67.3
6	7.94	50.53	30.08	75.5
7	4.46	39.37	43.11	82.8
8	5.22	39.50	42.31	82.7
9	4.73	41.05	38.02	79.0
10	6.44	51.94	29.88	74.2
11	4.76	49.49	30.28	72.1

TABLE III.—Ratios of Chemical Constants of Peppermint Oil Samples

Sample Number	$\frac{\text{Iodine Value}}{\text{Ester + Menthone}}$	$\frac{\text{Iodine Value}}{\text{Menthol}}$
1	2.03	1.17
2	2.09	1.29
3	2.07	1.34
4	2.11	1.25
5	2.08	1.36
6	1.98	1.49
7	1.74	2.10
8	1.74	2.09
9	1.85	1.92
10	2.04	1.43
11	2.00	1.46

Isotopic Exchange Equilibria

William H. Hamill, Fordham University and University of Notre Dame

The utility of isotopic exchange equilibria in accounting for various other equilibria in light-heavy water mixtures has been shown previously by the author.[1] The present work is an attempt to measure reliably some of these exchange equilibria by means of an improved technique, of which the essential improvement over earlier work[2] is the substitution of the immersed float for the pycnometer and the ability to carry out all operations in vacuum.

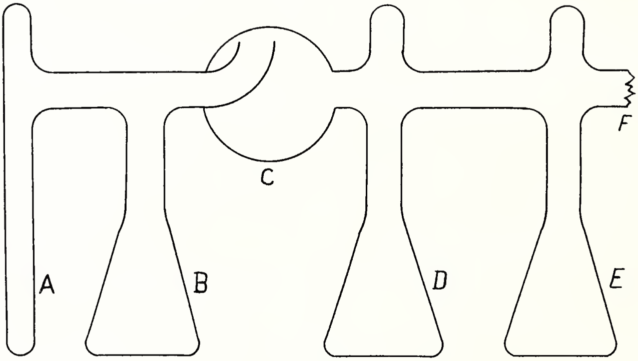

Fig. 1

About one gram of water (16% D_2O or 32% D_2O), which just fills a small ampoule with capillary stem, is weighed in the sealed ampoule and introduced into E (Fig. 1). The substance for exchange is weighed in a small open tube and introduced into D. The float is placed in A, the openings to A, D, and E sealed and D warmed on a water bath while the vessel is evacuated and then sealed at F. The water is liberated by immersing E in dry ice-ether, distilled into B, then poured into A and the density determined; the water is rinsed into C, distilled back to B, etc., and the density redetermined. The water is then distilled into the substance in D, and from D to E to B and the density again determined. This series of distillations is repeated as check.

The temperature is controlled by a glass-walled thermostat constant to ±0.001° and temperature differences observed on a Beckmann thermometer calibrated against one with Bureau of Standards certification. A cathetometer is employed for observations of thermometers and floats.

The densities of the floats were determined with reference to potassium chloride solutions whose densities were measured with 25 cc.

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[1] Hamill, 1937. Journ. Amer. Chem. Soc. 59:1492.

[2] Hamill and Freudenberg, 1935. Journ. Amer. Chem. Soc. 57:1427.

pycnometers and were reproducible to ten parts per million. Calibrated weights were employed and buoyancy corrections applied.

Quartz floats were used, and the temperature of the water adjusted at practically constant pressure (the vapor pressure of water) until flotation equilibrium was reached. Since floats have been employed at constant temperature and varying pressure, it is appropriate to remark that the floats employed here had apparent coefficients of compressibility, referred to water, of about $2(10)^{-5}$ per atmosphere. Since the velocity of the float altered by 0.03 cm./sec./1°, it was readily possible to detect differences in density of one part per million.

Blank runs showed that a negligible amount of atmospheric moisture was adsorbed on the glass walls of the vessel and that spattering, volatility of substance or hydrolytic products and reproducibility of measurements did not affect the density of water by more than one part per million except for hydroquinone which had a slight effect.

TABLE I.

Substance	K (16%)	K (32%)	K (0%)	K (calc.)
$CO(NH_2)_2$	0.609	0.614	0.60	
NaOH	0.484	0.578	0.39	0.35
$KHSO_4$	0.371	0.440	0.30	
KH_2PO_4	0.354	0.372	0.33	
$C_2H_4(COOH)_2$	0.572	0.632	0.51	
p-$C_6H_4(OH)_2$	0.590	0.632	0.55	0.55

The experimental results are summarized in Table I. A considerable discrepancy is observed between the equilibrium constants at 16% D_2O and at 32% D_2O, this constant being defined by the equations:

$$RH + HDO = RD + H_2O$$
$$(H_2O)(RD)/(HDO)(RH) = K$$

where RH is the equivalent of substance with respect to exchanging hydrogen, e.g. ½ $C_6H_4(OH)_2$. The observed discrepancies may be due to any or all of the following: (1) fractionation of the water upon distillation and a continuous series of equilibria with the substance in the process of crystallizing from solution, (2) failure of the assumption that in molecules containing two or more hydrogen atoms there is no effect upon other positions due to exchange in any given position, and (3) differences in solubility of RD and RH in the different heavy water mixtures. The first possibility is readily tested, and it was found, by experiments which will not be reported here in detail, that there is no significant trend in K for hydroquinone and succinic acid when up to 90% of these substances is crystallized from solution, by saturating at 100°C. and cooling to 25°C., before distillation begins. The second possibility may be eliminated by extrapolating K to zero per cent heavy water, which also eliminates the effects of HDO and D_2O upon solubilities, while the differing solubilities of RD and RH in any given aqueous medium are not susceptible to measurement and must remain as an unknown and possible source of error. The extrapolated constant is given in the table as K (0%) and may be compared, in two instances, with indirectly obtained constants.[3] Earlier measurements of K for hydroquinone, by the author, have been employed by Korman and LaMer,[4] in conjunction with their measurements on the quinhydrone electrode, to calculate several important equilibrium constants. The value of K for hydroquinone reported here is in essential agreement with the earlier measurement.

Summary

Isotopic exchange equilibrium constants have been measured by means of an improved technique for several substances at two concentrations of heavy water. Factors affecting their reliability are pointed out.

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[3] Hamill, 1937. Journ. Amer. Chem. Soc. 59:1492.

[4] Korman and LaMer, 1936. Journ. Amer. Chem. Soc. 58:1936.

SECTION ON GEOLOGY AND GEOGRAPHY

Chairman: S. S. VISHER, Indiana University

About fifty persons were present throughout the greater part of the session of this section. All papers were presented as scheduled. Professor Thomas M. Bushnell, of Purdue University, was elected chairman for 1939.

ABSTRACTS

Some little appreciated features of the desert. E. R. CUMINGS, Indiana University.—Most people who travel through the arid and desert regions of western United States and northern Mexico regard the desert as monotonous or fearsome—a hot, dry, and uninteresting region to be hurried across as quickly as possible. To the geologist who understands the play of weathering and fluvial processes that have shaped desert features, such regions are intensely interesting and even beautiful. The present note, which lays no claim to originality, is intended merely to call the attention of members of the Academy to some of these features—particularly the bolson (intermont basin), pediment, bahada, playa, and fan-bayed and pan-fanned mountains—and to the processes of sheet-flood and stream-flood which have produced these features. Adequate descriptions of these features and processes may now be found in the literature, particularly in the writings of W. M. Davis, W J McGee, D. W. Johnson, and A. C. Lawson, and in the Physiography of the Western United States, by N. M. Fenneman (1931), and the Treatise on Sedimentation (2 ed., 1932) by W. H. Twenhofel and others.

No New Corydon in the Huntington Quarry. E. R. CUMINGS, Indiana University.—The "new" quarry, mentioned by Mr. Breeze (Proc. Indiana Acad. Sci., vol. 47, p. 147) as containing an outcrop of the New Corydon formation, was worked many years ago, filled with water for many years, and pumped out and reopened about 1935, or '36. It exposes the same members of the Liston Creek formation as the France Quarry just west of it, now filled with water, and runs up into a bioherm at its east end. There is no New Corydon formation and no Huntington formation in this quarry.

The taxonomy of Indiana soils and its relation to other natural sciences. T. M. BUSHNELL, Purdue University.—In pedology the soil is defined as a natural body, occurring on the surface of the earth, characterized by conformable layers resulting from modification of parent material by physical, chemical, and biological influences acting through various periods of time. In other words, Soil = material × forces × time; but this broad generalization is limited because of the dominance of certain minerals as parent material and by the circumstances which condition the way the forces act upon the materials. Certain broad world relations result in climatic zones in which certain temperature and moisture conditions are important in soil formation. However, local relief brings about aeration, oxidation, and leaching of convex land forms, while nearby concave land forms may be more or less submerged by water, which results in reduction and in accumulation of organic matter, all of which results in very different soils. The nature and distribution of parent materials are related to many branches of geology. The nature of the forces and the way in which they work on the materials involve physics, chemistry, biology, and climatology. Ecology plays a large part in the way the biological factor affects soils. Since soil taxonomy involves the systematic arrangement of soils according to characteristics which more or less directly result from genetic factors, it follows that certain soil categories become good evidence of past or present existence of various geological, climatic, and ecological facts, and the soil map patterns may show very distinctly the distribution of these facts which belong to other sciences.

The Hazleton Bridge formation of the Upper Pennsylvanian of southwestern Indiana. Clyde A. Malott, Indiana University.—A locally quite fossiliferous formation consisting of 20 to 25 feet of shale, locally containing one or more thin coals, a thin limestone, and a black shale, succeeds the Merom or Inglefield sandstone of the upper Pennsylvanian system in Knox, Gibson, and Vanderburgh counties, Indiana. An excellent exposure of this shale formation occurs near the south end of the White River bridge on U. S. Highway 41 at Hazleton, and the formation may well be named the Hazleton Bridge formation. In this vicinity it occurs between two thick, massive sandstones, the Merom or Inglefield below and the Dicksburg Hills above. The latter receives its name from the circumalluviated hills one mile or more north and northwest of the Hazelton bridge outcrop. Good exposures of the Hazelton Bridge formation occur in the White River bluffs and deep ravines east of Hazleton and in the eastern end of the Dicksburg Hills along U. S. Highway 41 one mile north of Hazleton bridge; in the hills northwest and southeast of Patoka; at many places west and northwest of Evansville, where the formation is 80 to 100 feet above the West Franklin limestone; in the vicinity of Vincennes near old Ft. Knox and along the Robeson Hills bluff of the Wabash River in Illinois; and also at the Embarrass River bluff one-half mile east of Lawrenceville and along the south bluff of Indian Creek two miles south of Lawrenceville, Illinois.

Karst features in the badland shale areas of Petrified Forest National Park, Arizona. Clyde A. Malott, Indiana University.—Numerous small sinkholes occupy many of the slightly rounded and nearly level spur surfaces between the steep-sided ravines in the bare badland Triassic shale areas of the "First Forest," Petrified Forest National Park, east of Holbrook, Arizona. The sinkholes vary from a few inches in depth to as much as 10 feet, making mere dimple depressions to basins 15 or 20 feet across; and in places more or less longitudinal compound basins occur which have many sinkholes. The sinkholes are variably distributed and do not make any obvious pattern. The shale surfaces are entirely bare of vegetation and consist of a loosened friable veneer over the firm clay shale below. The sinkholes appear to have been formed wholly mechanically and entirely independent of solution. No limestone or other soluble beds are present. Apparently these upland clay shale spur areas dry out in the arid climate, and shrinkage cracks penetrate deeply below the surface. When the infrequent rains occur, much of the water falling on the inter-ravine surfaces enters the shrinkage cracks and reappears at lower levels in the ravines. The partly weathered, friable surface material apparently is carried little by little through the subsurface shrinkage cracks, and the sinkhole hoppers are formed. It may be questioned whether or not these sinkhole forms should be classed as karst. Certainly the region is not a karstland, but karst features frequently occur in regions which are not karstlands. My own view is that these features may well be referred to as karst features, since they are dependent upon the diversion of surface waters to underground routes, a phase present in all karstlands and in the development of many karst features.

Recent oil and gas discoveries in Indiana. M. M. FIDLAR and GORDON F. FIX, Indiana Department of Conservation.—During the past year, four new areas of oil or gas production have been discovered as a result of increased activity in the industry in Indiana. The new oil fields are the Prairie Creek pool in southern Vigo County and the Heusler and Point pools in southern Posey County. None of these three new oil fields have been outlined, and the approximate productive area can not yet be estimated accurately. In the Prairie Creek field, thirteen wells are producing oil.at depths of 2,130 to 2,175 feet from three pay horizons in the Devonian limestone immediately underlying the New Albany black shale. Four wells in the Heusler pool produce from the Waltersburg sandstone (Upper Chester) at an average depth of 1,790 feet. The wells in the Point pool obtain oil at an average depth of 2,700 feet in the McClosky oolitic zone of the St. Genevieve limestone, as well as from the Waltersburg sandstone, at a depth of 1,900 feet. The new gas area, the Ogle field, located in central Sullivan County, has four new wells producing gas from a Pennsylvania sandstone at an average depth of 795 feet. The combined initial production of all new wells drilled in the four fields described above total 1,941 barrels of oil and 7,350,000 cubic feet of gas per day. Even though settled production per day will be much lower, these recent discoveries are expected to increase substantially the annual oil and gas production of Indiana. It is also expected that additional important discoveries will be made during the next few months.

Reclamation in the Yakima Valley as a clue to the prospects for the Columbia Basin Project. WALLACE T. BUCKLEY, Indiana University.—The completion of the Grand Coulee Dam will mark another step toward the reclamation of 1,200,000 acres on the Columbia Plateau. The results already achieved in the Yakima Valley indicate that the completion of this project will permit an increase of 312,000 in the population of eastern Washington. Forage and cereal crops now occupy about three-fourths of the crop land of the several federal projects in the Yakima Valley, but as a source of income the fruit crop ranks first. The already extensive livestock industry is growing. The cereals produced, chiefly wheat, are not sufficient to meet local needs. The expansion of the fruit industry has been limited by a series of unprofitable years, and high freight rates and poor marketing facilities still stand in the way of its development. At present there is an apparent trend toward meeting a general deficiency in dressed meats, corn, and truck crops. At the present rate of population growth, the western states will require the production of about 10,000,000 acres within the next generation. Speculation in land values in the Columbia Basin will probably be rigidly controlled. Settlers will be selected as to experience in farming under irrigation and as to financial stability, and overdevelopment of the land beyond the available water supply will be prevented.

The Far Eastern conflict from the viewpoint of a geographer long resident there. FLOY HURLBUT, Ball State Teachers College.—Six factors of especial significance are: (1) the density of population of both Japan and China; (2) the limited resources for industrialization available in Japan; (3) the advantages of Japan over China due to more stimulating climate, more compact area, greater modernization, greater centralization of government, and greater militarism; (4) the fact that China has resources needed by Japan and affords a large, convenient market for Japanese manufactures; (5) Japan's attempts to break by force the drastic boycotts of Japanese goods in China; and (6) the close timing of Japan's aggression to take advantage of European difficulties. Although Japan is conceded great military superiority, its success to date suggests that its goals are still remote. Appreciation of Chinese qualities and geographic advantages leads not only to a sympathetic attitude but to belief that, in the end, Japan will not accomplish its objectives.

Climatic changes during post-Pleistocene times as indicated by fossil pollen in Indiana bogs and lakes. J. E. POTZGER, Butler University.—The pollen records from Indiana bogs show little fluctuation in climate, progress being remarkably uniform from cool-moist to warm-moist and warm-dry. In the western part of the state a warm and very dry period is indicated by prominence of grass pollen in later deposits. The conditions which controlled spruce-fir forest (cool-moist) changed comparatively rapidly in all parts of the state. Interpretation of climate is made difficult by the fact that pollen of oak and maple cannot well be defined to species and both of these genera have representatives of dry and wet habitats.

Further studies of certain atmospheric variations. A. V. LOTT, Sellersburg.—A circulation in any medium can occur only when a flow in a given direction is completed by a return flow in an opposite direction. This fundamental principle seems to be inseparably connected with all major air-flows throughout the world. When it operates in connection with another principle which causes air masses to become elongated in the direction of their most rapid motion, it causes great variations in the weather and the climate over widely extended areas. The complete development of an air-flow under the influence of these two principles apparently results in the formation of a complete climatic cycle. In North America the temperate climate becomes sub-arctic and then glacial. The glacial climate may be followed in certain sections by mild moist conditions, which are eventually replaced by another return to arctic cold. The arctic conditions eventually become sub-arctic and then temperate, and the cycle is completed. Charts show just how glacial and interglacial periods may develop in North America.

Geographic background of the Gallup, New Mexico, intertribal ceremonial. FRANK R. HALL, Purdue University.—Several aspects of this annual indigenous ceremonial reflect the geographic environment, for example, the costumes, ornamentation, implements, vehicles, and foods. It affords a view of the native—inherent rather than imported—arts, beliefs, modes, and other factors in Indian life.

Geophysics in the Training of a Geologist

Fred Serviss, Purdue University

The realization that geophysical methods might be of service in prospecting for ore bodies and likely areas for petroleum accumulation aroused extensive interest on the part of the mining and oil fraternity twenty or more years ago.

The continued increasing demands of modern civilization upon natural resources made it imperative to increase output and to develop new sources of supply. The evident and most likely areas of mineral wealth were either depleted or were being depleted by active mining. This left, as always, the less probable areas for future prospecting and development.

It will be granted that successful prospecting in the beginning was more luck than science. An increasing appreciation of geological control in ore deposition developed, in the old time prospector, a rule of thumb method which was fruitful when applied to exposed ledges. The recognition of the value of gossan, like the variability in the occurrence of gold leading to the prospector's statement that 'gold is where you find it,' is a well-known example. Continued prospecting under these crude beginnings resulted in the discovery of many famous mines. Drake's first oil well drilled in 1859 at Titusville, Pennsylvania, was, as history records, the first application of the anticlinal theory.

The increasing number of producing mines and oil wells served to create, after a time, a desire or what might be termed a need for more raw materials. Since the average rate of depletion of a mine is taken to be fifteen years and an oil field much less, it soon became apparent that to fill this growing demand new areas should anticipate their depletion. From this necessity arose the economic geologist. He brought to the aid of the mining industry an accumulation of knowledge of ore deposition, previous exploration, development, and production. By correlation, both geographical and geological, other areas were indicated as being economically favorable for reconnaissance. Mining engineers and others made possible the extraction of ore at greater depth and by decreasing cost of production made lower grade deposits available to industry.

The rate of discovery has not kept pace with the rate of consumption. Except for petroleum no major source of mineral has been found since 1850, with the exception of the copper in Africa and the lately discovered iron ores of India. No discovery of major value has been found in North America since 1910. The future looks to Asia and Africa for supplies, but it should not be held as patent that all other areas have been completely worked out since we have concerned ourselves to date only with surface or shallow indications. By the law of averages, mineral wealth should lie in the crust in equal or greater abundance than outcrops imply. Since economic or what may be termed applied geology has been of value in this connection, the profession should make use of any and all branches of science that will aid in this continued search for raw materials.

One of the latest and most promising is the science of geophysics. The science itself is not new; it is only an application of much that has been known for ages.

The use of lodestone, credited to the Chinese, dates back at least 3000 years B. C. The discovery of the laws of magnetic attraction and repulsion, the use of a pivoted needle by mariners, Columbus' discovery of the declination of the compass from the true north, and Gilbert's published *De Magnete* in 1600, which remained without addition until the nineteenth century, is a short history of magnetic phenomena. Modern geophysics has made much use of magnetic methods in prospecting.

Cavendish's experiments, using a crude torsion balance in determining the mean density of the earth, were made in 1798. It was not until the 1880's that Baron Von Eötvös devised a modification using the Cavendish principle and used it in the determination of local variations in gravity caused by rock masses. This principle is used in the modern torsion balance. From its use we have arrived at a conclusion as to the constitution of the earth's interior, and it has played its part in solution of the problem of isostasy.

The first basic statements, dealing with the question of transmission of earthquake waves, were made by Robert Mallet, an Irish engineer, about 1850. He was antedated by Reverend John Mitchell, who in 1760 stated that believed earthquake shocks travelled in a series of waves through the associated rocks. Mallet also suggested that an artificial earthquake could be created by explosions in the ground from which it should be possible to measure velocities of wave transmission. Our modern seismic methods are not so modern after all. Researches along this line have also given more information as to the condition and constitution of the earth's interior, which may be of only academic interest; yet the science and techniques are made use of daily in prospecting for underground information not only for oil but for other purposes.

Electricity and magnetism are closely related in the mind of the physicist; but in geophysics the property of current travel, the development of natural electric currents within the earth (sometimes called the natural battery action), and transmission of radio waves and distortion are separated from pure magnetic properties. Many electrical properties have been determined for rock masses. Delineation of faults, contact zones, the outlining of ore bodies in mineralized areas, and many other applications have given an insight into deeply covered ore zones.

Geologists should be made familiar with the various physical laws noted in the foregoing and their application to modern prospecting. Too few schools at present recognize that such should be part and parcel of geological training. It is not necessary that we train our men as geophysicists since that has become a specialized field, but we should train them in the basic principles on which the science of geophysics is built. The current argument as to whether or not the new science should be taught by the department of geology or the department of physics should not concern us at the present. That is more pertinent in the training of the specialist as to whether he major in physics and minor in geology or major in geology and minor in physics.

If it be granted that geophysics has a bearing on economic geology, should not our graduates be given some foundation in geophysical principles? This will require, no doubt, a more specialized course in physics specifically designed for this purpose, advanced courses in mathematics beyond the calculus, and a knowledge of mechanics, followed by a general geophysics course. In answer to the question, which is no doubt in the minds of some, as to where we are to find the time in an already crowded curriculum, my answer is—we should evaluate our curriculum—throw out outmoded courses, prune to the bone, and let our graduates be modern in concept and training.

Wind-Polished Pebbles from Northern Newton County, Indiana

M. M. Fidlar
State Department of Conservation

In the course of field investigations during 1938, the writer had opportunity to visit an interesting area in Lake Township, northern Newton County, near the center of the east line of section 33, T. 31 N., R. 9 W., approximately three miles south of Lake Village along U. S. Highway 41. In this vicinity in comparatively recent years, the stream which drains the northwestern portion of the old Beaver Lake swamp has entrenched itself deeply below the surface of the recent lake-bottom deposits. For thousands of years this area was covered by a vast glacial lake and swamp, but the urge for more farming land led some of the early settlers to dig a small drainage ditch to one end of the water area so as to be able to carry on further agricultural pursuits there. This ditch, owing to the fact that the original swamp area was perched several feet above the drainage lines to the north, was rapidly eroded downward to form the large open ditch in existence at present.

The entrenching of the drainage ditch allowed the wind to gain access to the thick deposit of lacustral white sand which was subjacent to the surface peat or muck of paludal origin. As a consequence of the resulting deflation, the sand was carried away to form small dunes

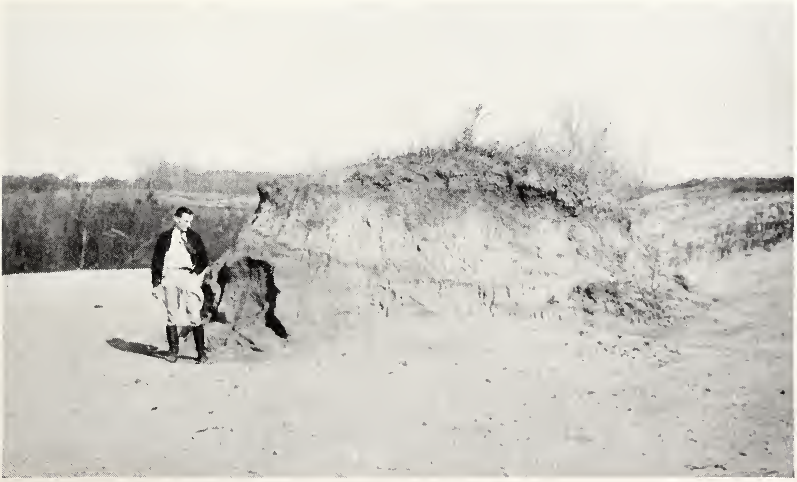

Fig. 1. White sand pedestal, capped by muck and vegetation, standing near the center of the Newton County blow-out. Pebbles on the floor near this feature are affected greatly by the action of moving sand.

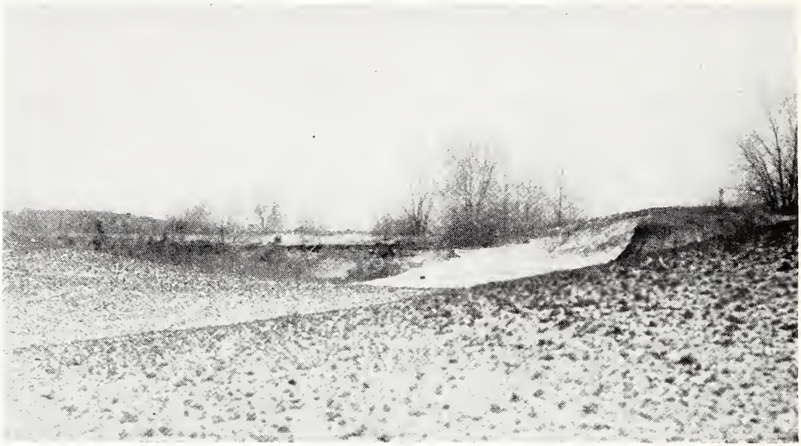

Fig. 2. General view of blow-out. In background is drifting sand along entrenched stream. In foreground are pebbles and pieces of bog iron ore concentrated by the removal of the lacustrine sand by the wind.

to the northeast, following the destruction of the peat cover by undermining. An interesting pedestal of white sand, capped by muck and vegetation, stands near the center of the area of deflation (Fig. 1). During the existence of the swamp near the line of junction between the peat and the underlying white sand, nodules of bog iron ore were formed by the action of ground water heavily charged with iron minerals. At the site of the blow-out in discussion these nodules of limonite and sand, too heavy to be moved readily by the wind, are concentrated upon portions of the sand floor as the sand is blown away.

The white sand, forming a part of the lacustrine deposits, contains numerous pebbles and cobbles of varying size, which, like the bog iron nodules, are concentrated upon the floor of the blow-out, resembling the "hamada" or pebble pavements of desert regions (Fig. 2). The pebbles of varying composition have been attacked by the particles of moving sand rolled along the surface by the prevailing winds and have attained in some cases a beautiful "windpolish." In many cases partially-buried pebbles have taken on "desert varnish," a phenomenon due to the concentration of iron minerals on surfaces below the ground. Such pebbles, so far as the writer is aware, have never been described from Indiana although they are not uncommon in many arid regions where sand dunes are constantly moving.

The impact of moving sand in the Newton County blow-out does not have the same abrasive effect upon all pebbles. The sandstone fragments show no visible effect of the natural sand-blast although it is possible that such types of stone may be shaped to some degree by the rounding of corners and sharp edges. Shale pebbles seem to react in much the same way as those composed of sandstone. Compact limestone or slatey shale pebbles have assumed a certain amount of windpolish, and sharp edges have been rounded and smoothed before polishing. Laminated limestone pebbles have been grooved and faceted in a remarkable manner by sand-abrasion in the Newton County blow-out.

Igneous and metamorphic rocks have reacted most impressively to the attack of the driving sand. Granite and related igneous rock pebbles are etched as they lie upon the floor of the blow-out so that the harder mineral grains and crystals stand out in bas-relief. The white sand, composed in the main of quartz grains, readily attacks the mica and hornblende of the granite, whereas the feldspar crystals are only slightly reduced and the quartz grains undergo very little alteration with the exception of the frosting of the surface.

The most pronounced wind-polish has been attained by the pebbles composed of gabbro and basalt, fine-grained igneous rocks. Many pebbles of this composition exhibit rounded edges and wind-shaped facets on the windward side, and all surfaces with which the wind comes in contact are finely polished. On the leeward side, however, the pebbles have the frosted appearance characteristic of glacial pebbles, transported some distance from their parent outcrop, and show no effect of the abrasive action of the wind-driven sand.

Mineralization in the Harrodsburg Limestone

GORDON F. FIX
Department of Conservation

Mineralization in sedimentary rocks, far from any known igneous activity, has been an interesting study in economic geology since such deposits were first discovered. Some of the more important lead and zinc deposits, as well as cadmium and other metals, are present in such environments. Deposits where the minerals are present in quantities great enough to make them of economic importance have been rather thoroughly investigated geologically, but in many areas there are smaller deposits which have not been the subject of much detailed study. The attention of the author was first called to the mineralization in the Harrodsburg limestone by Professor Ralph Esarey, of the Geology Department of Indiana University, and to Professor Esarey he wishes to acknowledge indebtedness for advice and many helpful suggestions, both in the field and in the laboratory. This paper represents a progress report on a study not yet completed. Mineral occurrences, relationships to the limestone, and paragenesis are described for only a limited area. At the present time the study has been extended to include all the Harrodsburg limestone in Indiana, and continued work may modify or completely change theories as herein postulated.

Much of the mineralization in these minor deposits occurs in geodes. These nodular masses of mineral matter occur in many places in the United States, but the most prolific and widespread horizon is in the Lower Warsaw Series of Indiana, Illinois, and Iowa. In this formation the geodes are perhaps the best developed and most abundant and contain the greatest variety of minerals of any place in the country.

In Indiana the Warsaw Series is represented by the Harrodsburg limestone. Perhaps the best exposure of this limestone in the immediate vicinity of Bloomington is in the quarry about one mile north of the city on State Road 37, where from 30 to 40 feet of the formation is exposed in a total formational thickness of from 60 to 90 feet. The floor of the quarry is not more than ten feet above the contact between the Harrodsburg and the Borden or Knobstone. It was from this quarry that most of the specimens were collected for study.

The Harrodsburg limestone is typically coarsely crystalline and contains great numbers of crinoids and bryozoans. In certain localities the formation becomes more shaly. This is especially true in the quarry north of Bloomington where the lower 15 to 20 feet of the 40 feet exposed is a greenish, shaly limestone, interfingering with more calcareous lenses. Toward the top of the section much of the argillaceous material disappears, and the formation assumes the light grey (often bluish), coarsely crystalline, very fossiliferous aspect of the typical limestone. In the zone of oxidation the color changes to a distinct buff or tan due to the presence of the hydrous oxide of iron. The line of transition between the oxidized or weathered and the fresh limestone is very sharp in most places, there being practically no gradation.

Mineralization in the quarry is not confined to the geodes, some of the best occurrences of minerals being in drusy cavities, along joints, fractures, bedding planes, and stylolites, or disseminated in the limestone close to one of the avenues of lower resistance to mineralizing solutions.

The term "geode" comes from a Greek word meaning earthlike, because the usual form of the geode is spheroidal. Several definitions have been proposed, but none of them quite fills the requirements. Perhaps the best definition is one given by Van Tuyl:[1] "Geodes are rounded or nodular masses formed by the inward growth of mineral matter upon the walls of pre-existing cavities. They may be solid or hollow, depending on whether or not the process of filling has been carried to completion."

The definition, as stated, is too inclusive. Not all masses of mineral matter growing inward from the walls of pre-existing cavities can be classed as geodes. Many are cavities containing only a few crystals or having the walls only partially covered with mineral matter. The term geode should be restricted to those masses having a complete outer siliceous shell and the interior either wholly or partially filled. An amended definition, embodying the restrictions as stated above, follows: Geodes are rounded or nodular masses of mineral matter, having an outer siliceous shell and growing inward by the addition of mineral matter on the interior of the shell. They may contain one mineral or several and may be hollow or solid. Continued deposition tends to produce complete filling.

Typical geodes of the Harrodsburg limestone are practically limited to the lower ten or fifteen feet. They occur mainly in shaly facies; and, although generally small, are well-developed. One stratum about three feet above the floor of the quarry is almost one continuous geode, so closely are they spaced. These are about two inches in diameter and one inch thick, on the average, and are composed of crystalline quartz with subordinate amounts of calcite and rare occurrences of pyrite and sphalerite. This one horizon represents the only definite limitation of geodes to one particular stratum in the vertical section. Elsewhere, geodes are scattered indiscriminately, some areas being almost or totally barren and others having geodes in considerable abundance. The latter fact may be attributed to the greater permeability of one particular area to the percolating solutions.

Intermingled with the geodes and extending up to the top of the section are irregular cavities (druses) ranging in size from one-fourth inch to a foot or more in the longest dimension. Some of these apparently were initial cavities, that is, they were present when the limestone was deposited. An example of this type is the hollow space between the two halves of a brachiopod shell. Others, and by far the most common, appear to be due to differential solution by percolating waters above the water table and along stylolite seams, bedding planes, and joints and fractures. Some cavities, occurring in rather even textured, fresh limestone are difficult to explain either by the initial theory or by differential solution. These are located at some distance from any apparent path for solutions. A possible explanation is that an initial cavity, affording an opportunity for percolating waters to become active, has been enlarged by the solvent action of these waters. An interesting feature of these mineralized cavities is the presence of a number of country rock inclusions within the later mineral matter. Inclusions of this type are not common and occur mainly in those cavities which have a preponderance of dolomite. The presence of inclusions would seem to indicate one of two things: either deposition has taken place on the outside of the initial layer of mineral matter, by replacement of the limestone, at the same time that deposition was taking place on the interior; or, in extremely irregular cavities, small masses of the limestone have been cut off from the rest and included between the crystals, with some replacement.

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[1] Van Tuyl, F. M., 1921-1922. Iowa Geol. Sur. **30**: 305.

There are several types of mineralized cavities. One type, which occurs mainly in the geode zone and for a distance of about ten feet above it, is particularly filled with rhombohedral flesh-colored crystals of dolomite with smaller amounts of calcite and tabular crystals of gypsum, with or without quartz. A second type contains calcite with two generations of crystals; a third contains calcite and drusy quartz crystals; and a fourth contains quartz, calcite crystals, and later mammalary calcite and aragonite. The last three types are mainly above the geode zone, and the second is confined principally to the upper 15 feet of the section. Where the zone of weathering comes in contact with the second type, the calcite crystals are coated with limonite. In the limestone immediately adjacent to these cavities, especially those containing dolomite, glauconite, and pyrite, this occurs rather frequently. Sphalerite crystals are common, and millerite has been found in only two instances. Barite was found in one large cavity, with dolomite and calcite.

Along joints, fractures, bedding planes, and stylolites the chief minerals are glauconite, calcite, sphalerite, and pyrite, with little quartz. The minerals are not confined to the surface of the joint or fracture but may partially replace the limestone for a distance of from one to two inches in from the surface. Many fracture planes, which would otherwise go unnoticed, are made conspicuous by glauconite, which not only fills the actual break, but, in many cases, makes a gradational contact with the limestone on both sides. Irregular, vertical veins of calcite occur locally. Considerable limestone has been removed by solution along bedding planes, and a residue, in places one inch or more thick, of very glauconitic argillaceous material has been left. The chief mineral along such planes is pyrite, which is contained in the limestone adjacent to the plane as crystals up to one-fourth inch long. Chalcedony, showing Beekite rings, and calcite occur along stylolite seams. The black material present is mainly carbonaceous matter, with innumerable microscopic pyrite crystals imbedded in it.

It is apparent from a study of the minerals present that there has been a more or less definite order of deposition. This is especially true in the case of the earlier minerals, which are also those occurring most abundantly and consistently. In all cases where the three predominant minerals are present, the order is: quartz, dolomite, calcite. The order of deposition of the minor minerals is more difficult to determine, since they are present in small amounts and are not all present in one locality. It seems probable that more than one period of deposition has occurred. Crystalline quartz, dolomite, calcite, sphalerite, and some pyrite belong to the first period. Mammalary calcite, aragonite, and more pyrite represent the second period. Glauconite probably belongs to the second period, but its relationships to the other minerals and its low solubility make this a matter of conjecture. Its deposition may have covered a longer period than that of any of the other minerals. Barite, gypsum, and limonite are the latest minerals, the last two having resulted from the alteration of calcite and pyrite. Some examples of the paragenesis of minerals are:

1. Geode: Quartz-dolomite.
2. Druse: Quartz-calcite-limonite.
3. Joint surface: (including one inch of country rock) Calcite-sphalerite-pyrite.
4. Irregular cavity: Quartz-dolomite-calcite- (pyrite inclusion) glauconite-pyrite.
5. Solid geode: Quartz-minute pyrite crystals.
6. Druse: Dolomite-calcite-gypsum.
7. Fracture plane: Glauconite-pyrite.

Several theories have been advanced to explain geodes. One states that a crinoid calyx may be replaced by silica.[2] Deposition begins between the plates which make up the calyx, and, as more silica is added, the plates are gradually forced apart and finally are engulfed in the silica. Bassler[3] says that many of the geodes can be traced directly or indirectly to a crinoidal origin, since there are large numbers of these organisms present in the rocks. He also says that the common brachiopod, *Athyris lamellosa,* may be next in importance. If conditions are right, almost any fossil can be replaced by silica. Some of the geodes of the lower Harrodsburg may have been formed by the replacement of fossils; but, for the most part, the lower beds in the section studied are shaly and not very fossiliferous. In no case was a geode found which had only partially replaced a fossil. Such replacement is common in the geodes of the upper part of the Borden formation.

Van Tuyl[4] ignores fossils in his theory for the formation of geodes in Iowa and Illinois. He states: "The origin of the geodes in the region studied is believed by the writer to be related to the calcareous concretions which originally must have been very abundant in the beds and which are still preserved in some localities. These nodules, being more soluble than the enclosing rocks, have been in large part removed, thus leaving cavities in which the geodes could be formed. * * * The removal of the calcareous nodules which, it is assumed, preceded the geodes, implies an interval of solvent action during which the beds were above ground-water level. The growth of geodes, on the other hand, undoubtedly took place below the ground-water level."

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[2] Shaler, N. S., 1899. Geol. Soc. Amer. Bull. 10:253.

[3] Bassler, R. S., 1908. Proc. U. S. Nat. Mus. 35:133.

[4] Van Tuyl, F. M., *op. cit.* 344-346.

The writer does not wholly agree to any theory heretofore proposed, since insufficient evidence has been obtained to date on the Indiana geodes. Continued work may shed some light on this complex problem. In the vicinity of this study there are very few calcareous nodules left; so replacement must have been very complete, if such replacement has taken place. Fossils play an important part in the formation of geodes in the Upper Borden where over-silicification of brachiopods and corals is very apparent. The only fossils occurring abundantly in the lower part of the Harrodsburg in this quarry are crinoid stems; and these, while silicified, do not seem to have contributed in any way to the formation of the geodes. Also, crinoids occur only in the calcareous phases of the Lower Harrodsburg and are not present in the shaly members where the geodes occur.

The source of the minerals seems to be in the limestone itself. The Harrodsburg is overlain by the Salem limestone, which will average close to 96% pure calcium carbonate; and it is underlain by approximately 600 feet of intercalated shales and sandstones, comprising the Borden or Knobstone formation. It is highly improbable that either of these formations could have been the original source of the metallic minerals or that ascending thermal waters could be responsible, because of the widespread occurrence of the minerals. Apparently small amounts of the minor minerals were present in solution, either in the present combinations or in different ones in the Warsaw sea, and were precipitated out along with the lime. Water percolating through the limestone has taken the minerals into solution and redeposited them under favorable conditions. The composition of these solutions must have changed considerably or have been highly complex during the period of deposition, since part of the minerals are soluble in acidic and part in alkaline solutions. The composition also must have varied locally, because the same sequence of minerals is not present in all cases. Change in composition of the solutions probably was the chief factor controlling deposition, although the latest minerals, amorphous calcite and aragonite, and some encrusting chalcedony appear to have been deposited by evaporation.

Nothing can be said definitely as to the time of deposition, because there is nothing on which to base estimates. The process of taking into solution and redepositing obviously covered enormous periods of time and may still be going on in places where the limestone is below the water table. In the quarry studied, however, deposition seems to have been stopped for some time with corrosion of existing crystals and formation of secondary minerals, such as limonite, gypsum, and barite, the latest stage.

The Heavy Minerals of the Mansfield Sandstone of Indiana

H. RICHARD GAULT
University of Missouri[1]

Introduction

This investigation was undertaken for the purpose of obtaining any evidence which might distinguish stratigraphic horizons in the Mansfield formation and give information as to its source. With this objective in mind, the writer collected samples and studied sections of the formation throughout the area in which it outcrops during the summer of 1937. A total of 239 samples were taken from 16 localities (Fig. 1), and the material was studied by various laboratory methods, chiefly heavy mineral determinations and mechanical analyses, at the University of Missouri during the school year of 1937-38.

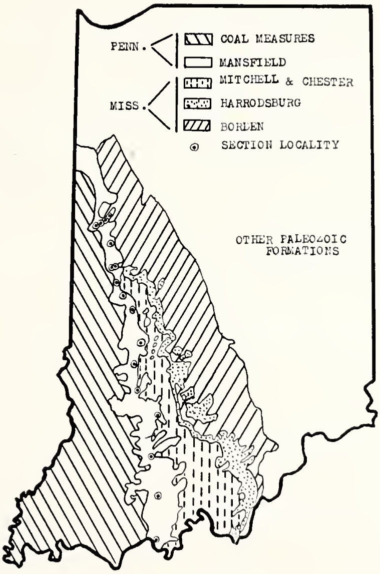

Fig. 1.

The Mansfield Sandstone

The Mansfield sandstone, named by Hopkins (1) in 1895, is a basal Pennsylvanian sandstone of Pottsville age, resting unconformably on the underlying formations. The stratigraphic hiatus reaches a known maximum of about 1500 feet in the northern part of the area, where the Mansfield rests on the New Albany (Dev.) shale near Remington, Indiana (2). Toward the south the Mansfield rests on successively younger formations. In Turkey Run State Park the underlying formation is the Borden (Miss.), and near Greencastle, the Mansfield lies on the St. Louis (Miss.) limestone. At the Ohio River, over 600 feet of Chester (Miss.) sediments lie below the Mansfield (2), in addition to the Borden shale, and the Harrodsburg, Salem, and St. Louis limestones.

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[1] Now at The Pennsylvania State College.

The outcrop is a long narrow belt striking NNW-SSE in western Indiana for a distance of some 170 miles along the west flank of the northwest arm of the Cincinnati Arch. The formation is covered by glacial drift in Illinois (3), but the outcrop is continuous across the Ohio River into Kentucky.

The base of the Mansfield is very uneven, having local hills and valleys which sometimes show a relief of 150 feet or more (4). The maximum thickness of the formation in the northern part of the area is less than 100 feet but to the southward increases to over 300 feet near the Ohio River.

The Mansfield is a brown, red, purple, buff, tan, or white sandstone at the outcrop with occasional local conglomeratic, shale, and coal phases. The color depends on the amount and nature of the iron oxide present and changes from section to section, although differences in surface color in individual sections are ordinarily slight.

The sandstone is usually massive, but thin-bedded phases are present. Cross-bedding is a characteristic feature of the Mansfield sandstone. The sandstone is medium-grained, the majority of the grains ranging from .15 mm. to .6 mm. with sub-angular to sub-rounded shape. Modification of the quartz grains by secondary growth is quite evident. The chief cementing materials are silica and iron oxide, although rarely calcium carbonate and pyrite cements were noted. Despite the secondary growth on quartz grains, the friability is determined largely by the amount of iron oxide cement. In most cases the sandstone is easily crushed.

Field and Laboratory Procedure

A sample of the fresh rock was taken every five feet vertically in each section. All samples were crushed and coned and quartered until a portion weighing about 25 grams was obtained. This portion, from which the excess iron oxide was removed with warm dilute hydrochloric acid, was used in the heavy mineral separation. All samples were washed by decantation to remove the fine material.

The heavy liquid employed in the separation was tetrabromoethane (Sp. gr. 2.9), a modification of the procedure described by Milner (5) being used. The heavy liquid was washed from the grains with naphtha and recovered by evaporating the naphtha.

The actual study of the heavy fractions was made with a binocular microscope. Several samples were studied in great detail and the minerals identified by the oil immersion method with a petrographic microscope. Whenever a new mineral or a new form of a previously known mineral appeared, a petrographic microscope was used for positive identification. Approximately 400 grains of the entire fraction of each sample were counted and the percentages of each mineral computed from this count. The light fractions were cursorily examined under a binocular and petrographic microscope to determine the minerals and the amount and variety of feldspar.

Minerals of the Mansfield Sandstone

Light Minerals.—The light minerals (Sp. gr. less than 2.9) in the Mansfield are quartz, feldspar, and chert.

Quartz.—The quartz grains generally compose 95% or more of the sandstone and range in size from .05 mm. to .6 mm. The larger grains are frequently well rounded and frosted, but the smaller grains are more angular and clear. Secondary growth has taken place to some extent on most of the grains, with the later quartz in optical continuity with the original grain. Almost all quartz grains carry inclusions of rutile, gas bubbles, or unidentified particles.

Feldspar.—Feldspar grains do not exceed 2% in the samples studied. In the order of abundance the varieties are orthoclase, microcline, and probably albite (Ab^{95}), for a few grains have fine plagioclase twinning striations with indices equal to or below 1.540. Most grains are cloudy and anhedral, but some grains are clear or have clear borders and are subhedral. It is not known whether the clear borders indicate authigenic growth.

Chert.—Usually the percentage of chert is less than two, although some conglomeratic phases consist quite largely of reworked chert from the St. Louis limestone.

Heavy Minerals.—The heavy minerals make up a minor portion of the sand, less than 1% by weight. The following minerals with a specific gravity of more than 2.9 were identified; biotite, brookite, chlorite, garnet, hornblende, ilmenite, leucoxene, magnetite, muscovite, pyrite, rutile, tourmaline and zircon.

Biotite.—The biotite grains are cleavage flakes which have been battered and bent. All grains have been bleached to some extent and occasionally approach muscovite in color.

Brookite.—Brookite was identified by its optical properties: indices of refraction much greater than 2.06, birefringence very high, and positive biaxial interference figure with very strong dispersion. It occurs as tabular and prismatic grains, brown to yellow in color and usually cloudy in transmitted light. The average size of the grains is .05 mm.

Small well-developed crystals are sometimes found projecting from leucoxene grains which resemble the material identified as brookite in form, color, and often in size. These crystals were probably developed *in situ,* as evidenced by their sharp edges and the soft nature of the leucoxene matrix. The action of moving water would soon tear the crystals loose from such soft material.

McCartney (6) describes a similar occurrence in the Chester sands of Indiana and also concludes that they were developed *in situ.* The small crystals were identified by McCartney as brookite, but Tyler and Marsden (7), in an X-ray study of leucoxene, worked over McCartney's slides and could not identify brookite.

Chlorite.—Thin books and flakes of chlorite with smooth white edges range in color from deep bright green to light silver green. Biotite is usually present in those samples containing chlorite.

Garnet.—A light pink variety of garnet is most common, but dark, almost opaque varieties, and light cinnamon colored grains were seen. The light colored grains often show a rectangular patterning and are not worn. The dark brown grains are sub-angular. Grains vary in size from .1 mm. to .4 mm.

Hornblende.—Dark green cleavage flakes of hornblende are present. All grains observed were fresh in appearance.

Ilmenite.—Ilmenite occurs as sub-angular to rounded grains which have a sub-metallic luster. Very rarely ilmenite was found altering to leucoxene. It is recognized that other opaque minerals may have been confused with ilmenite.

Leucoxene.—Leucoxene grains are smooth and polished, white to buff or even brown, and also earthly, porous, and sometimes pitted. Microcrystalline material, almost opaque under the petrographic microscope, was identified as leucoxene and may be an early stage in the alteration of this mineral to rutile or brookite. Grains of this description were fused with borax and the purple titanium bead obtained. Brown (8) has also reported leucoxene of this same general description. The description of Tyler and Marsden is typical of the material in the Mansfield.

Magnetite.—The octohedral habit is the most common form, but occasional grains are nearly spherical. The crystal forms and magnetism serve to distinguish magnetite from ilmenite. The grains average .1 mm. in diameter.

Muscovite.—Clear ragged flakes of muscovite are most abundant. Aggregates of very fine material occur, and, in samples rich in mica, small books of clear muscovite with smooth white edges are numerous. The white edges seem to be the result of bumping and grinding between coarser material.

Pyrite.—Pyrite occurs in the form of aggregates and clusters with some poorly developed cubes of pyritohedrons. The crystal forms and the cementing nature indicate that the pyrite is secondary.

Rutile.—Rutile grains are straw yellow to fox-red and silver gray to black. The dark grains have a strong, satiny, metallic luster showing a deep, rich, ruby red color in transmitted light. The light colored grains are rounded whereas the dark grains are sub-angular. Lath-shaped and knee-shaped grains were found occasionally.

Tourmaline.—The dominant color of the tourmaline is brown with green, blue, grey, and colorless grains much less common. The shades of brown vary from almost colorless to nearly black. Light green and blue grains are more abundant than the dark shades. The black and deep brown grains are at times spherical, pitted, and frosted. The common shapes are long prismatic grains with fractured ends, biscuit-shaped fragments, and irregular grains. Grain sizes range from .06 mm. to .4 mm. averaging .15 mm. Some tourmaline grains contain unidentified inclusions.

Zircon.—A pink variety is the most abundant, but purple, pale yellow, and colorless grains also appear. A complete gradation from purple to colorless is found. Spherical grains and prismatic forms with rounded terminations prevail, but prismatic grains with slightly worn or fresh pyramidal faces occur in every sample. The yellow and purple varieties are spherical and frequently frosted. Grains vary in size from .04 mm. to .2 mm. but the average is .1 mm. The larger sub-hedral grains often carry inclusions of crystals and other material.

Mechanical Analysis of the Mansfield Sandstone

In addition to the heavy mineral studies, the writer also made mechanical analyses of 222 samples to determine the size distribution of the sands. The accompanying histogram (Fig. 2) is made from the average figures of all samples. All tests were made on a Tyler Ro-Tap testing machine. The effective size is .100, and the uniformity coefficient is 2.66. The majority of the individual analyses show good sorting, and their cumulative curves are similar to those of the St. Peter made by Dake (9).

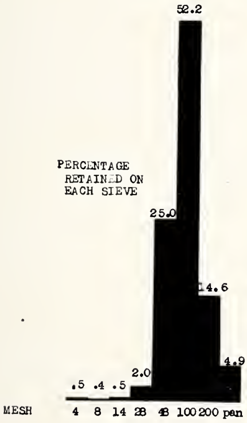

Fig. 2.

Discussion of the Heavy Mineral Suite

The dominant allothogenic minerals of the 239 samples studied are leucoxene and zircon, with ilmenite, tourmaline, rutile, muscovite, and brookite, common but less abundant. Biotite, chlorite, garnet, hornblende, magnetite, and pyrite occur sporadically.

Heavy Mineral Percentages

Persistent Minerals		Sporadic Minerals
Leucoxene	40-70%	Chlorite
Zircon	20-50%	Biotite
Ilmenite	5-20%	Garnet
Tourmaline	5-20%	Hornblende
Rutile	1-10%	Magnetite
Muscovite	1-10%	Pyrite
Brookite	1-10%	

A change in the percentage of leucoxene results in a change in the percentage of zircon, but there is no change in the percentage of the other minerals. Ilmenite is more or less abundant than tourmaline in a particular section, but the relative percentages for each locality do not vary greatly. Rutile grains constitute about 5% of the heavy fraction in the majority of samples, and the lighter colored varieties are more numerous. Muscovite is usually low except in shale samples. Brookite may disappear almost completely from any one sample or series of samples but is present in all sections.

The sporadic minerals may be present in all samples, but the amount is so slight that they could easily be missed in the grain counts. Chlorite and biotite are usually associated with each other. Garnet grains were seen in very small numbers and in many samples were not observed. The pyrite is probably secondary in all cases.

The heavy mineral species of the Mansfield are uniform in their occurrence and distribution. The suite is always the same regardless of regional location or stratigraphic position. The percentages of individual minerals vary somewhat from sample to sample, but the relative magnitude for each mineral is constant.

The suite is not characterized in any way by mineral content, peculiarities, or percentages which would permit the differentiation of the Mansfield into units within itself or distinguish it definitely from some other sandstones. Evidence for this statement is presented below in the discussion of the source of the sediments. It would be unwise to use the heavy minerals for placing the Mansfield in well logs. Perhaps with information about the formations above and below the Mansfield, such as heavy minerals, insoluble residues, lithologic characters, and paleontological evidence, the data presented in this paper might be of some value for that purpose. The heavy mineral suite alone, however, is inadequate evidence for recognizing the presence of the Mansfield in wells or for correlation between wells and outcrops.

Source of the Mansfield Sediments

The dominant heavy minerals are few in number, are all very stable minerals, and may well have had a long previous history as clastic grains. It appears, then, that the immediate source should be sought for in pre-existing sediments.

Schuchert (**10**) states that at the beginning of the Pennsylvanian, the United States was a lowland surrounded on the south and east by a mountainous borderland. Cumings (**11**) pictures the Mansfield sea as having its eastern edge near the eastern edge of Indiana. During the interval between the deposition of the Mississippian and Pennsylvanian sediments, Mississippian and older rocks were extensively weathered and the less stable minerals removed. The area covered by the Mansfield sea was underlain by sedimentary rocks, and the land mass to the northeast and east had many sediments exposed. On the advance of the Mansfield sea, the source, then, of most of the detrital material was the old erosion surface, and the greater part of the material had undergone at least two erosion periods. It seems likely that, since the land mass to the northeast and east was adjacent to the Mansfield sea, a greater amount of material would come from this area than from more distant land masses.

The presence of any of the less resistant minerals, for example, the fresh grains of hornblende, may be due to exposure to erosion for the first time in the Pennsylvanian period of igneous and metamorphic rocks. Russell (12) has shown that minerals, even the less resistant species, may be transported at least 900 miles and show neither wear nor alteration.

It would be difficult to say exactly what pre-existing sediments furnished the Mansfield material. The presence of chert in the sand indicates that the surrounding Mississippian and older limestones were contributors. The distance materials were brought is also a difficult question, but undoubtedly much of it was local, i. e., the area in which the Mansfield now occurs. At Attica, the Mansfield rests on the Borden, and the lower two feet of the Mansfield contains small fragments of the Borden shale. As drainage developed, the later sediments were brought in from more distant places.

The small and constant number of minerals might indicate a very local and protected area of source, but the size of the region studied, the thickness of the formation, and the findings of other writers seem to refute this and support the view that the source area was rather general.

Other writers have reported suites similar to the Mansfield from various formations. Derry (13) reported a similar suite in some Ordovician rocks of Ontario; Thiel (14) and Tyler (15) found a similar group of minerals in the St. Peter sandstone of Wisconsin and Minnesota; McCartney (6) had an almost identical suite from the Chester sands of Indiana; Lucas (16) reported a comparable assemblage in some Pennsylvanian rocks of Oklahoma; Kelly and Beutner (17) found a very small group of minerals, all of which are present in the Mansfield, in some Pennsylvanian sandstones of Michigan which may be time-equivalents of the Mansfield; Cordry (18) found a similar group in Pennsylvanian and older rocks in the Ozark region of Missouri; Brown (8) reported a large amount of leucoxene and other Mansfield minerals in some Permian sands of the Mid-Continent region; and there have been other suites reported in this country and abroad, which, although not quite like the Mansfield suite, yet have a small number and constant number of the more stable minerals most of which are found in the Mansfield.[2]

These findings show that the heavy minerals of the Mansfield or a similar group are common and evidence that reworked sediments of a general area of some size were the source of the Mansfield detritals. These findings also show that it would be unwise to use the heavy mineral suite alone for identifying the Mansfield as discussed earlier.

McCartney suggested that the Chester sands represented material from igneous rocks with no intermediate period of deposition. The writer questions the lack of intermediate deposition but favors, instead, the idea of a similar origin of the Chester sands as for the Mansfield.

Acknowledgments

The writer is greatly indebted to Dr. W. A. Tarr and Dr. W. D. Keller, of the University of Missouri, for assistance and criticism in the

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[2] See abstracts in Boswell (19).

laboratory and in the preparation of the paper; to Professor E. R. Smith, of DePauw University, for aid in the field and the reading and presenting of this paper; and to Dr. C. A. Malott, of Indiana University, for information and aid in locating sections.

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Indiana Data on Lightning, Hail, Squall-Wind, and Tornado Frequencies and Damage

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Lightning

Data on the frequency of lightning storms in Indiana are gathered incidentally by the regular, full-time weather bureau stations, which report on the frequency of nearby thunderstorms. Thunderstorms occur on about 50 days each year in central Indiana, on about 45 days in northeastern part of the state, and on about 55 in the southwestern corner. During the summer each locality has an average of about two thunderstorms each week. Lightning from distant storms, too far away to have local significance, may be visible on one or two additional nights a week in summer. Most thunderstorms cover only about one-third of the state and many of them cover less area than that. Moreover, sometimes two or even three thunderstorms affect a locality during a single 24-hour period. Hence, it is probable that about 200 individual thunderstorms occur in Indiana each year.

As it takes the average thunderstorm about four or five hours to cross the state and there are an average of hundreds of lightning flashes per hour, it is quite possible that millions of bolts of lightning are discharged in Indiana each year. Of these a few thousand strike trees, buildings, fences, or the ground. Most of the taller trees, especially the more isolated ones, have been struck at one time or another. Telephone, telegraph, and power lines are frequently damaged. Lightning is a major cause of fire to farm buildings. The U. S. Weather Bureau investigated the average annual fire losses to farm buildings caused by lightning as recorded in an eight-year period, 1915-1922. A recent official map shows that in Indiana nearly a half-million dollar loss a year is caused thus. The average annual totals for certain states are as follows: Indiana $491,000, Ohio $685,000, Illinois $1,094,000, Michigan $289,000, Kentucky $266,000, Pennsylvania $656,000, Missouri $478,000, Iowa $611,000, Minnesota $305,000, Oklahoma $784,000, and New York $838,000.

In Indiana lightning causes most fires in summer, chiefly because lightning is much more frequent then. The higher air temperatures of summer and the fact that the combustibles are often dryer than in the cooler months also is more conducive to the rapid spread of summer fires.

Thousands of livestock are killed annually by lightning in Indiana. From the reports of those coöperative observers who have taken especial pains to gather data on these losses in Indiana (for example, Fred Baker of Rockville, Parke County), it seems probable that on the average more than 4000 hogs are killed annually in Indiana and more than 1000 cattle.

Several hundred people annually are killed by lightning in the United States, seven a year in Indiana, on the average (according to mortality data in the Statistical Bulletin of the Metropolitan Life Insurance Company, June, 1936).

The mortality in four southeastern states (Georgia, Florida, Alabama, and Mississippi) and in three Rocky Mountain states (Colorado, New Mexico, and Arizona) is nearly four times as great as in Indiana in proportion to population. In several other states, however, the death rate is considerably less than in Indiana. This is particularly true for the states with many people living in cities, where very few people are killed in proportion to population, and in the states on the Pacific Coast and New England. In the Pacific States there are few thunderstorms in the lowlands as there is little summer rainfall. In New England thunderstorms are relatively uncommon, and likewise, the population is largely urban.

By the conventional census divisions, the death rates per million population are: Rocky Mountain states 8.3, East South-Central states 7.1, South Atlantic states 6.0, West South-Central 5.6, West North-Central states 3.4, East North-Central states, which includes Indiana 2.1, Middle Atlantic states and New England 1.3, Pacific states 0.2. In deaths per ten thousand square miles, however, the rates are different, and Indiana is in the second class, less unfortunate than Kentucky, Ohio, and West Virginia but worse off than most of the nation.

Although the chances of being killed by lightning are very small in Indiana, almost negligible in the cities, some readers may be interested to learn of ways of reducing the chances.[1]

Hail

Violent thunderstorms are frequently accompanied by hail; occasionally hail falls in sufficient quantities to cause considerable damage.

Indiana had, during a 15-year period recently studied by the U. S. Weather Bureau (1916-1930), an average of 4.8 damaging hailstorms each warmer season (April 1 to September 30). Indiana had fewer hailstorms recorded officially as "damaging" than any nearby state, except Illinois and Missouri, which had about as many in proportion to area. In contrast with Indiana's 4.8 damaging hailstorms a year are the following annual average totals: Ohio 8.3, Illinois 6.9, Kentucky 6.2, Michigan 12.6, Wisconsin 8.9, Missouri 5.2, Iowa 21.6, Montana 21.6, and Kansas 33.4.

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[1] In this connection the following are also helpful:

U. S. Dept. Agr., Farm. Bull. 1512, 1926.

U. S. Bur. Stand., Handbk. 17, 1936.

The following extract may be justified here:

"(a) Do not go out of doors or remain out during thunderstorms unless necessary. Stay inside of a building where it is dry, preferably away from fireplaces, stoves, and metal objects.

"(b) If there is any choice of shelter, choose in the following order: 1. Large metal or metal-frame buildings. 2. Dwellings or other buildings protected against lightning. 3. Large unprotected buildings. 4. Small unprotected buildings.

(c) If remaining out of doors is unavoidable, keep away from: 1. Small sheds and shelters if in exposed location. 2. Isolated trees. 3. Wire fences. 4. Hilltops and wide open spaces.

(d) Seek shelter in a cave, a depression in the ground, a deep valley, the foot of a steep cliff, in dense woods or a grove.

Data on the extent of damage from hail in Indiana are not yet available. This is partly because hail seldom causes extensive damage in this state. In certain states where more damage is done, more data have been accumulated. For example, in Iowa, which has more than four times as many damaging hailstorms as Indiana (twice as many in proportion to area), the property loss averages more than ten million dollars a year. In a single county, representative of the northwestern part of the state (which has more hail damage than the state average), hail caused an average property loss of $227,000 a year for a 15-year period. If Indiana's hail damage is proportionate to that of certain comparable areas in other nearby states, the property damage is in excess of $1,000,000 per year on the average.

Occasionally hailstones reach the size of baseballs or even larger. Large hailstones occasionally kill even people in some parts of the world. Indeed, some scores of hail-induced-fatilities occur annually, on the average, in southeastern Europe and southwestern Asia. None in Indiana, however, are known to the present writer.

Rarely the hail is so small as to closely resemble snow. A remarkable summer snow storm in Indiana is worthy of mention here.

"The most remarkable warm season snowfall in Indiana occurred on July 2, 1924, in Wabash county. There, with the temperature at the nearest Weather Bureau Station nearly 70 degrees, during a hail storm, snow fell to a depth of eight inches on a small area."

An account of this remarkable fall was published in the Bulletin of the American Meteorological Society for August, 1924, and the report was investigated by J. H. Armington, state director of the United States Weather Bureau, Indianapolis, who was convinced of the correctness of the report. This remarkable snowfall was associated with a violent hailstorm which had a distinct tornado-like funnel. Hail covered the ground for some distance around the patch of snow.

Squall-Winds

Violent windstorms, nearly all of the thunderstorm-squall type, cause extensive loss in Indiana. Indeed, for the 20 years of a recent special study by the U. S. Weather Bureau (1916-1935) Indiana suffered a total estimated property loss of $7,656,000 from violent winds not tornadoes. This was one-fiftieth the total loss for the nation as a whole for such storms. As there are 48 states, it might seem that Indiana has had only slightly less than its proportionate share of such loss, but Indiana is a small state. In proportion to area, Indiana (with 7.66 million loss) had more property damage from violent windstorms not tornadoes than did Ohio (5.15), Michigan (9.3), Missouri (3.3), Minnesota (5.9), Kentucky (6.3), Iowa (7.3), Illinois (9.7), or Wisconsin (10.7).

Thunder-squall damage occurs occasionally in all parts of the state. Among the seasons it is decidedly most frequent in summer. Indiana's losses in five-year periods were as follows: 1916-1920, $1,005,000; 1921-1925, $2,408,000; 1926-1930, $3,913,000; 1931-1935, $330,000. The average annual loss is about $383,000, but the variation from year to year is great. Indiana's greater than average recorded loss for squall winds may be due partly to the fact that the State Director of the Weather Bureau, J. H. Armington, has made especial efforts to gather information of this type. Much of Indiana has, however, more than the average number of farm buildings per square mile, more telephone and similar poles than most states, and because of the earlier settlement than true for most of these states, more old buildings.

Tornadoes

A study of tornado frequency in the United States made by the U. S. Weather Bureau disclosed that for the 20 years, 1916-1935 inclusive, Indiana had 66 tornadoes or an average of 3.3 per year. This number was larger than for Michigan (3.0 a year) or Kentucky (1.2), but smaller than for Illinois (4.0), Wisconsin (4.3), Missouri (6.6), or Tennessee (3.6). Indiana has only about one-fourth as many tornadoes as Iowa or Kansas (15 or 14.6 per year respectively). These latter states are much larger than Indiana, however. In proportion to area, Indiana has about one-half to one-third as many tornadoes as the states wherein they are most frequent, Iowa to Arkansas, inclusive.

In the approximately 2,800 tornadoes recorded in the United States during the twenty years, 1916-1935, 5,224 people were killed by tornadoes; and property losses in excess of $230,000,000 were sustained. Losses in excess of $100,000 were sustained in 375 tornadoes although million dollar losses were caused by each of 30 tornadoes.

Partly because tornadoes have played only a minor role in Indiana, no detailed account of Indiana's tornadoes has yet been prepared. With few exceptions, tornadoes damage only a minute fraction of the area of the state. So few occur and the damaged strip is so narrow that the chances of any one spot being hit by a tornado are very small. It has been calculated, for example, that even in the part of our country where tornadoes are most frequent (southern Iowa, Missouri, Arkansas, and eastern Kansas) the chances that any given half-mile square of land (160 acres) will be crossed by a tornado in a century is only 1 to 1600. As most tornadoes devastate a strip only a few hundred feet wide, a farm might be crossed several times without the buildings being demolished. Many buildings are damaged without the inhabitants being killed.

In Indiana tornadoes are least rare in the lower Wabash Valley of the southwestern part of the state. They are next least rare in central Indiana. They are very rare at the surface near Lake Michigan and in the more rugged parts of the state. Bloomington, for example, has not been appreciably damaged by a tornado during its history, which extends about 120 years. Presumably this is largely because a wide belt just west of the city is quite rugged. Tornadoes which cross rugged areas tend to rise above the surface where they do little or no harm.

Indianapolis, in the midst of a plain, has been affected by several tornadoes, three in one decade. But fortunately no very severe one has plowed through the city. A moderately severe one, that of May 18, 1927, demolished many buildings in the western part of the city, then rose above the surface passing over the downtown part of the city. It caused a property damage estimated at more than $2,000,000 but only two deaths.

The question of whether or not it may be possible to cause tornadoes to rise above the surface and thus be rendered almost harmless is of interest.

Tornadoes are violent whirls, started by opposing winds and associated with sharp contrasts in temperatures. They occur only when sharp vertical temperature gradients are present. They are formed in the clouds and extend down to the ground only where the temperature of the surface air is relatively warm (as compared with the higher air). Tornadoes rise above the surface again wherever the surface air is relatively cool. Evidence on these points is extensive. For example, tornadoes are most numerous, as to time of day, when the surface air is relatively warm in the early evening. Occasionally, to be sure, a tornado which started in the afternoon continues on its course until midnight but only if the surface air is relatively hot. Records show that the few nocturnal tornadoes occurred on nights when because of cloudiness and high relative humidity nocturnal cooling had been slight. Tornadoes after nightfall occur on "hot sultry nights," never the reverse.

In their seasonal distribution, also, tornadoes are most numerous at seasons when the vertical temperature gradient is greatest. For the mid-west this is during the spring. In the south the temperature gradient is greatest and tornadoes most numerous, earlier than here, in the early spring. Conversely, in the northern states and southern Canadian provinces temperature gradients are greatest in the summer, and hence tornadoes are most frequent then. In certain other parts of the country along the southern Atlantic coast, for example, temperature gradients are often great in the autumn; and hence tornadoes are relatively frequent then.

The influence of temperature gradients on tornadoes is illustrated in other ways. For example, although several tornadoes have entered the western outskirts of Chicago, none have closely approached Lake Michigan. When tornadoes occurred, winds from off Lake Michigan cooled the downtown part of the city. Finally, at Tokyo, Japan, on September 1, 1923, several typical tornadoes developed as a result of the conflict of air movements produced by the great fire and the cooler higher layers of air associated with the typhoon. Excellent photographs of two of these tornadoes indicated that they were closely comparable with those of the mid-west.

If the presence of a surface layer of relatively cold air causes an approaching tornado to rise above the cool air, as appears almost proved by the foregoing data, then a city on a plain, such as Indianapolis, if it could be bathed in cold air on the approach of a tornado, would be thereby protected because the tornado would rise above the buildings and people.

Tanks of rustless steel containing air compressed to say 20 atmospheres (300 lbs. per square inch) could be buried at various points throughout the city, being especially numerous in the western end of the city and just west of the down-town district. Such tanks should be connected electrically with the office of the U. S. Weather Bureau in the city. When telephone reports and supplementary evidence indicated that a tornado was almost at hand approaching the city, the official should close the electrical switch which permits the covers of the tanks to fly off, allowing the compressed air to escape rapidly.

The escaping air would greatly lower the temperature of the surface air, producing a protective cold layer over which the tornado would rise. The cost of maintaining the tanks, including the interest on their installation, would be great; but at present some millions of dollars are expended annually in Indianapolis for tornado insurance premiums. And although insurance reduces the individual's loss, it does not reduce the total loss.

Indiana Distribution and Yield of Corn, Wheat, and Oats*

STEPHEN S. VISHER, Indiana University

Indiana has been an important agricultural state because much of it has climatic, soil, and topographic conditions favorable for the growth of valuable crops, because there is a market close at hand, and because many competent, informed farmers live within its borders.

In this article the distribution and yield of three chief crops, corn, wheat, and oats, are discussed, the basis being the annual county totals and averages reported by the U. S. Census and the U. S. Department of Agriculture Coöperative Crop Reporting Service at the Experiment Station, Purdue University. The special purposes of this study are to disclose the relative importance of these crops in the various parts of the state, with recent changes therein and the relative yields received in the average, favorable, and poor years. These factual data are presented chiefly by maps. Some attempts are made in the text to interpret or explain the contrasts most conspicuous on the maps. The present paper is an elaboration of certain topics discussed in more general terms in earlier ones.[1]

Corn Distribution

Corn is grown on almost every representative Indiana farm. On the average for the state, about 25 acres per farm is devoted to corn. The average farm of the southeastern and also of the northern counties has about 15 acres and of the hilly south-central counties about 10 to 12 acres; in the large region called central Indiana, on the other hand, the average farm has about 30 acres of corn even though it includes a total of only 80 acres.

A map of the counties showing the number of acres devoted to corn for the average of ten recent years, not published here because of lack of space, discloses that most counties of central Indiana have between 60,000 and 90,000 acres of corn, depending partly on the size of the county. The largest county totals are found in the northwestern part of central Indiana where two relatively large counties, Benton and Tippecanoe, devote, on the average, somewhat more than 100,000 acres to corn. Several other counties also approach that total. In the Wabash lowland of southwestern Indiana, the county acreage in corn is almost as great as in much of central Indiana, several counties having more than 50,000 acres. In most of the rest of southern Indiana, however, the county totals are less than 30,000 acres; in six counties they are less than 20,000 acres.

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* Read in the General Session of the Academy.

[1] Visher, S. S., 1927. Geography of Indiana agriculture. Proc. Indiana Acad. Sci. 37:101-116; Econ. Geog. Indiana pp. 108-149. New York, 1923.

Since the counties vary in size, it is illuminating to compare the average acreages devoted to corn with the total area of the county. Figure 1 shows the percentage of the total land area which has been planted to corn during a recent decade. This map discloses that on the average more than one-quarter of all the land (which includes roads, railroads, towns, and cities) is devoted to corn in much of central Indiana, where each average square mile has about 180 acres of corn. Three large areas devote more than 30% of all their land to corn. The largest of these is Benton and two adjacent counties; other high counties are Clinton and Tipton, north of Indianapolis, and Hancock, Rush, and Shelby, east and southeast of Indianapolis.

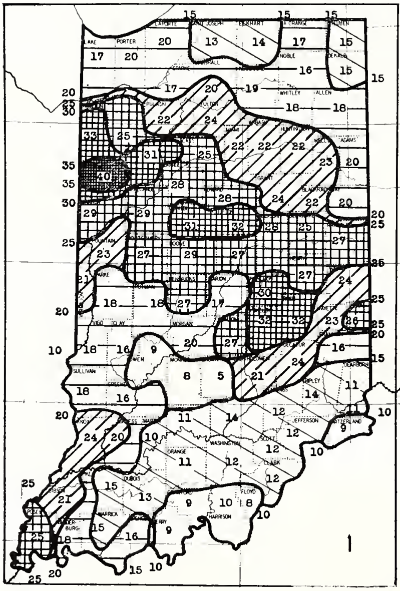

Fig. 1. Corn: Percentage of total land area which is planted to corn (15 year average, 1923-1937).

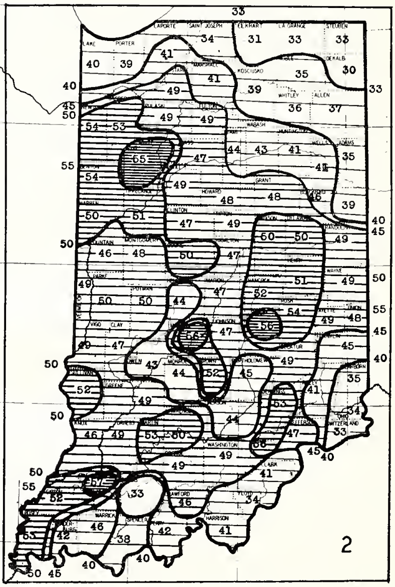

Fig. 2. Corn: Percentage of cropland planted to corn (10 year average).

A large part of southern Indiana, except the Wabash lowland, devotes less than 15% of its land area to corn, which is also true of 4 northern counties. In other words, they have less than 90 acres per average square mile. Eight southern counties devote less than one-tenth of their total area to corn; Brown County only one-twentieth.

The percentages of the cropland devoted to corn are dealt with in Figure 2, which affords a number of surprises. Even where, as in Brown County, only one-twentieth of the total land area is in corn, more than half of all the cropland may be so used. This means that considerable areas are planted to corn in successive years. This map makes conspicuous, in a way not so easily shown otherwise, that corn is a major crop in almost all parts of the state. Only in Dubois and 4 extreme northeastern counties is less than one-third of the cropland used in any particular year for corn, and of these low counties the county with least, DeKalb, devotes 30% to corn. In only a dozen additional counties, bordering those just mentioned, plus 3 at the extreme southeast, does corn occupy less than 40% of the cropland. In most of the counties it occupies approximately one-half of the cropland; in seven counties corn occupies 54 to 57% of the cropland. The largest region where corn occupies less than 40% of the cropland, in the northeast one-eighth of the state, is often too cool at night in spring and autumn for good corn growth, because of the relatively high latitude and altitude. The other areas with less than 40% of their cropland in corn contain much hilly land where sheet erosion and gullying has been especially extensive and where the better farmers no longer plant corn on hillsides.

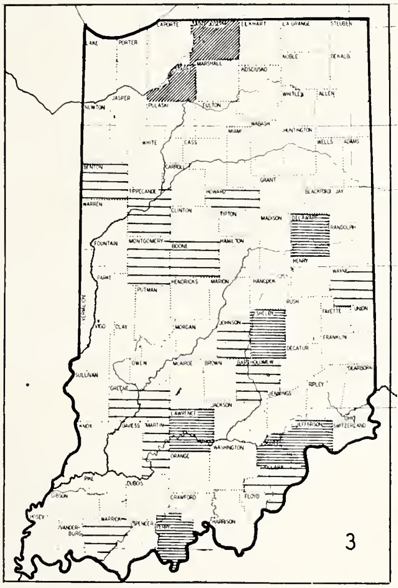

Fig. 3. Corn: Changes in acreages of 10% or more for average of last five years as compared with preceding decade. Inclined shading means gain; horizontal shading, loss; close, 13-15%; light, 10-11%.

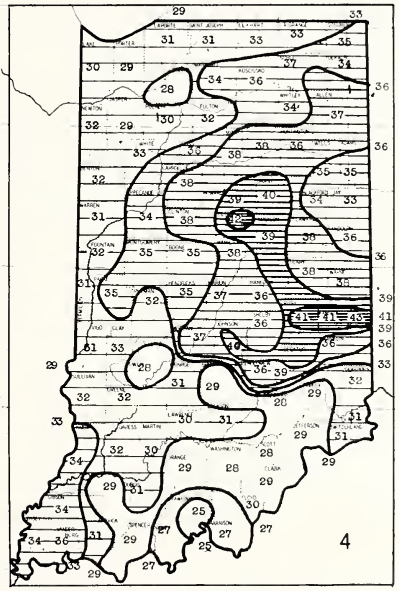

Fig. 4. Corn: Average yields, county averages (15 year averages). Bushels per acre.

Figure 3 discloses the changes in acreages devoted to corn, based on the average of the last five years as compared with the average of the ten preceding years. It shows that in only two counties, St. Joseph and Starke, has there been a gain as great as 10%; on the other hand, there has been a loss of 10 or 11% in many central and southern counties, and a loss of 13 to 15% in six counties, all in the southeastern third of the state. This decline has been encouraged by the soil conservation program of the federal government, but much of it merely continues a decline which has taken place for decades, following serious soil erosion on hillsides and resulting in reduced yields and the cessation of farming of many tracts.[2] Moreover, most of the counties with considerable declines (Fig. 3) still devote more than half of their cropland to corn. This means that "corn follows corn." In other words, crop rotation is incompletely practiced, despite the ever louder expert urging that rotation pays. As more and more farmers come to practice complete rotation, the areas devoted to corn will decrease until nowhere will more than half of the cropland be devoted to corn.

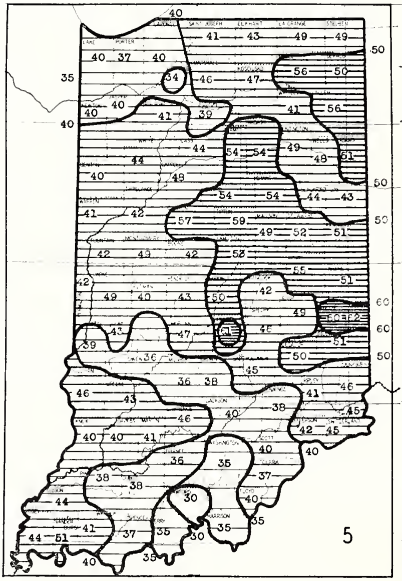

Fig. 5. Corn: Maximum county average yields (highest in 15 years, 1920-1936, except 1921-1922). Bushels per acre.

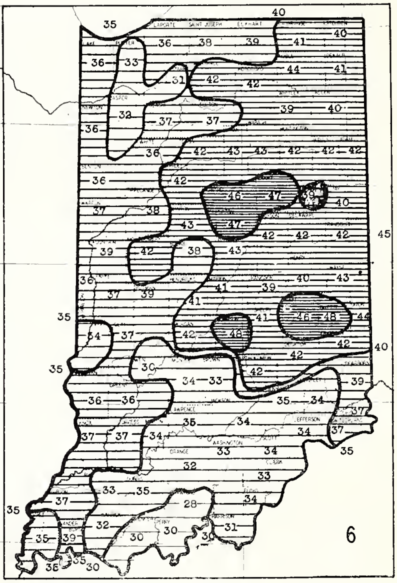

Fig. 6. Corn: Yields in a good year (county average). Only in the best two years of a decade are higher yields received. Bushels per acre.

Average Corn Yields

Despite the fact that Indiana has an exceptionally dependable climate and consequently far less fluctuation in crop yields than have most regions, nevertheless, there is considerable variation from year to year. Hence an average based on a considerable number of years is notably more accurate than the yield for a short period. Figure 4 shows the yields by counties from an average of 15 recent years. It discloses that two large areas have an average yield of 29 bushels per acre or less; an area which is even larger receives an average of over 38 bushels. By far the larger of the poorer areas is in southern Indiana and includes thirteen counties, three of which (Harrison, Perry, and Crawford) receive an average of 27 bushels per acre or less; indeed, the 15-year average for Crawford County is only 25 bushels per acre.

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[2] Visher, S. S., 1937. Indiana regional contrasts in soil erosion and their chief causes. Proc. Indiana Acad. Sci. 46:143-159.

The highest average yields of corn are received in east-central Indiana, extending from Grant and Tipton counties to Rush, Johnson, and Union. In this area yields of 39 or more bushels are normal. In other words, farmers here have a right to expect nearly half again more corn per acre than the average farmer of the one-fourth of the state where corn yields are relatively low. The counties with highest corn yields for the average of these 15 years are Grant and Johnson, where the average is 40 bushels, Rush and Fayette with 41, Tipton 42, and Union 43.

The wide variation among the counties in average yields is related to variation in soil, temperature, rainfall, and in the percentage of the rain which soaks into the ground. Of course care and seed also count. The northwestern area with lower than average yields has much sandy or mucky soil, and it also has relatively frequent drouths. The southern low-yield area has much thin soil on the sloping land, and the bottom lands are being injured by the transfer thereto of infertile materials eroded from the hillsides. Moreover, some of the level upland has poor "white clay" soil. Likewise, more of the rain in southern Indiana falls as sharp showers, which fact means that more of it runs away and hence less of it soaks in. Only rain which soaks in is really helpful to crops. Abundant data on Indiana's contrasts in rainfall intensity reveal that southern Indiana receives a much larger percentage of its rainfall in hard downpours, much of which runs away if there is any appreciable slope, carrying with it soil.[3] The lower yields in southern than in central Indiana are also partly the result of more damage from insufficient rainfall in July and often excessively high temperatures.[4] Dr. Rose has found that when there are many days with temperatures above 90° the yield suffers.[5]

Maximum Corn Yields

Not only are average yields interesting, but one wishes to know how large a yield may sometimes occur. Of course on choice land in exceptional years, yields of 150 bushels per acre are occasionally received. But what about the average of all the cornfields of a whole country?

Figure 5 shows the greatest county average yield received during 13 recent years for which county records are available. In the year of best corn yields (for most of the state this was 1925 or 1937) 22 counties, one-fourth of the state, had average yields of 50 bushels or more per acre, five counties had averages of 55 to 59 bushels (Allen, Noble, Clinton, Tipton, and Henry), and three counties received 60 bushels or more (Fayette 60, Johnson 61, and Union 62). On the other hand, even in their best year, in one-fourth of the state's counties, the average was 40 bushels or less; in five counties it was 35 or less, and in Crawford it was only 30.

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[3] Visher, S. S., 1938. Rainfall intensity contrasts in Indiana, causes and consequences. Geog. Rev. 28:627-637. (Abstracted in Proc. Indiana Acad. Sci., 47:147-148, 1938.)

[4] Visher, S. S., 1936. Indiana regional contrasts in temperature and precipitation, with special attention to the length of the growing season and to non-average temperatures and rainfalls. Proc. Indiana Acad. Sci. 45:183-204.

[5] Rose, John K., 1932. Climate and corn yield in Indiana 1887-1930. Proc. Indiana Acad. Sci. 41:317-321; corn yield and climate in the corn belt. Geog. Rev. 26:88-102, 1936.

Minimum Corn Yields

A map, not published, shows the smallest county average yields and may advantageously be briefly described. Although Indiana is deservedly famous for the general dependability of its corn crop yields as compared to Illinois, Iowa, Missouri, and other more western parts of the Corn Belt, nevertheless, in the worst of recent years surprisingly low county average yields have occurred in certain parts of the state. For some sections the worst year was 1930; for others it was 1934 or 1936. For the state as a whole the smallest average yields were received in 1901 (19.8 bushels), in 1887 (20.0 bushels), in 1890 and 1893 (24.7 bushels), in 1934 (24.8 bushels), and in 1924 (25.6 bushels).

Along the Ohio River in south-central Indiana are five counties which received in their worst year recently less than a 10-bushel average, with Harrison and Floyd having averages of only 7.3 bushels. Ten additional nearby counties had 15 bushels or less. Northwestern counties having relatively low yields were Lake and Porter with 11 each, Jasper and Pulaski with 12, and Benton, Warren, and Starke with 14.

The highest average minimum yields in this period are 25 to 33 bushels per acre and are located in east-central Indiana. Tipton, one of the flattest counties in the state favored with good soil, has the highest minimum yield, 33 bushels per acre, more than four times the average minimum yields for two southern counties (Harrison and Floyd).

Normal Range in Corn Yields

In addition to the map of average yield (Fig. 4), of maximum yield (Fig. 5), and of minimum yield (not published here), two maps of the yield in four years out of five have been prepared. One of these shows the yields which are exceeded in four years out of five; in other words, it shows the yield of the next to the poorest year in a decade. The other map shows the yields which are received in the best one-fifth of the years—eight years of each decade do not have yields as high as these. These maps show distinctly better than does Figure 4, of the average yield, which may reasonably be expected. Only rarely are the yields greater than those given in Figure 6 or less than those given in Figure 7.

Figure 6 discloses that in all but the poorest year of a decade, yields of 40 bushels or more have been received as county averages in more than one-third of the state (mostly in the east-central and northeast) and more than 47 bushels in four central and eastern counties. On the other hand, in nearly one-third of the state, mostly in the south, yields in excess of 35 bushels occur only once a decade. In the poorest counties, Crawford to Spencer, yields of over 30 bushels are as unusual as this.

Figure 7 discloses that in the poorest two years of a decade the yields averaged higher than 30 bushels in about one-third of the state and more than 41 bushels in three counties. On the other hand, in much of the state, especially at the south, west, and north, yields of less than

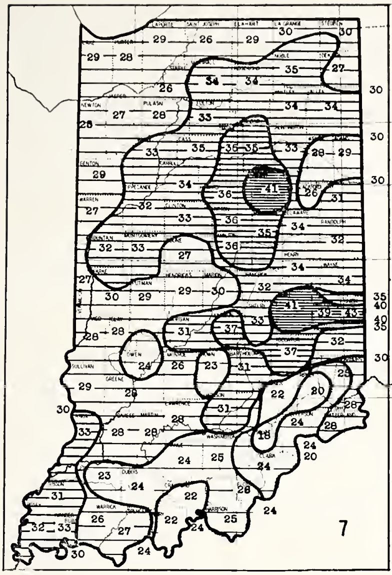

Fig. 7. Corn: Yields in even a poor year. Only the poorest two years of a decade have smaller county average yields. Bushels per acre.

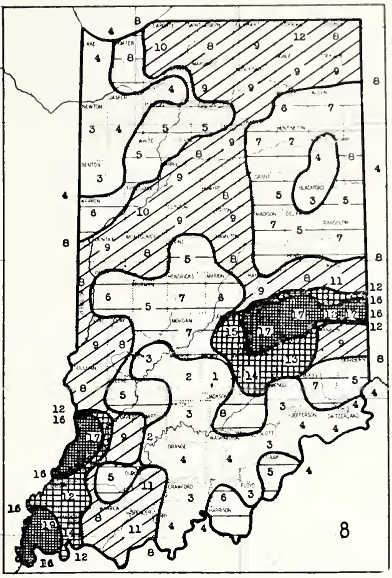

Fig. 8. Wheat: Percentage of total land area which is sown to wheat, by counties (15 year average, 1923-1937).

30 were received in the two poorest years of a decade. In many southern counties yields of less than 25 bushels are as frequent as this, and in five counties yields of less than 22 bushels.

Wheat Distribution

The amount of land devoted to wheat in Indiana is much less than for corn, and there are much wider variations from year to year. This reflects the fact that Indiana's climate is generally not so well suited to wheat, that the yield varies more widely, and that the price fluctuations are more significant. Whereas most of the corn is fed to livestock on Indiana's farms, most wheat is sold in competition with the wheat of other areas, including foreign countries. The fact that Indiana's wheat is soft and not so suitable for bread flour as the harder western wheat is a major reason that much of Indiana's wheat is shipped out of the state to less discriminating bread eaters.

A map of the number of acres sown to wheat for the average of the past decade, not published here, shows that more than 40,000 acres is devoted to wheat on the average in only four counties, all in the southern half of the state. In about one-third of the state 20,000 or more acres per county are sown to wheat. The largest region of this type is in the northwestern part of the state, followed by the southwestern corner and by six counties (Shelby and neighboring counties). Four groups of counties which devote less than 10,000 acres each to wheat are seven situated in south-central Indiana, six at the extreme

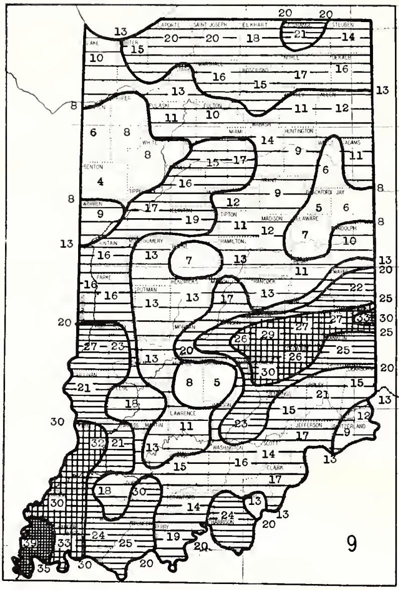

Fig. 9. Wheat: Percentage of the cropland in wheat (10 year average).

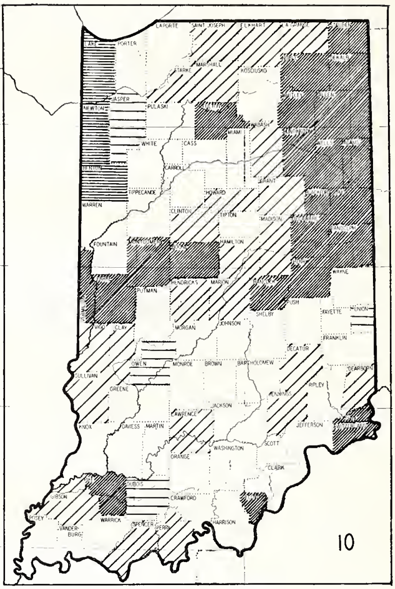

Fig. 10. Wheat: Changes in acreages of 10% or more for the average of last five years as compared with preceding decade. Horizontal lines mean loss; light 10-19%; close, 20% or more. Tilted lines mean gains; light, 10-29%; dark, 30% or more.

southeast, and seven in the north, partly in the northwest and partly in the northeast. Aside from three small counties (Ohio, Blackford and Floyd), the only county having less than 3,500 acres in wheat is Brown, which has only 1,000. The counties with largest average acreages are Knox, 55,800; Posey, 47,400; Shelby, 45,000; and Rush, 43,800.

Figure 8 shows the percentage of the total area of each county which was sown to wheat for the average of the 15 years, 1923-1937. It makes conspicuous the fact that two areas devote relatively large shares of their area to wheat, one at the southwest and the other at the southeast, some distance north of the corner. In these areas about one-sixth of all the land is used for wheat, in Posey County 19%. On the other hand, a large area in south-central Indiana and smaller ones in northwestern and northeastern Indiana devote less than 8% or even less than 4% of all their land to wheat. The southern large area with little wheat contains much hilly land, ill-adapted to wheat; the northwestern area contains much sandy land also unfavorable to wheat. The counties which devote one-sixth or more of their land to wheat are situated in the southern half of the state, rather than in the northern half, partly because the higher average winter temperatures are more favorable.

Figure 9 discloses that in much of the region south of the National Road (No. 40) more than one-fifth of the cropland is devoted to wheat; north of that line an average of only about one-eighth is so used. Exceptions to the rule that about one-fifth of the cropland of southern Indiana is devoted to wheat are found in Brown (5%), Monroe (8%) and some adjacent or Ohio River counties where about one-eighth or less is so used. Likewise, along the northern border of the state, more of the cropland is devoted to wheat than is true for the average of northern Indiana.

The counties with the largest proportion of their cropland in wheat for the average of a recent decade are Posey 39%, Vanderburgh 33%, Knox 32%, Bartholomew 30%, Shelby 29%. Conversely, the counties with least wheat relatively are Benton, Blackford, Brown, Jay, Delaware and Boone, with from 4.4 to 7%.

Figure 10 shows the changes in the amount of land devoted to wheat for the average of the last five years as compared to the average of the preceding ten years. Whereas 19 counties had shown a 10% or greater decrease in land in corn and only two had shown a 10% or greater increase, the opposite condition prevailed as to wheat. Only seven counties showed more than a 10% decrease; one-third of the counties of the state showed an increase of more than 10%. The decreases are in the northwest and south, and the increases are most general in the northeast quarter; but more than a dozen counties of the southern third of the state also show increases. The increases are largest in the section where relatively little land is devoted to wheat without any obvious reason (see discussion of Fig. 8). Another factor is that in recent years a new variety of wheat has been developed which grows better than those previously available in the northeastern part of the state.

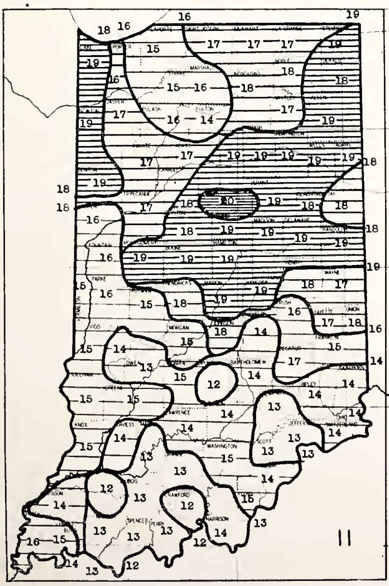

Fig. 11. Wheat: County average yields (18 year average, 1920-1937). Bushels per acre.

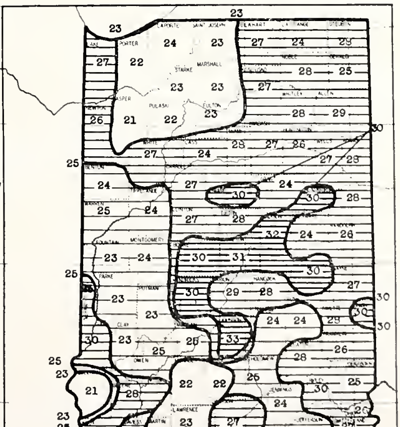

Fig. 12. Wheat: Maximum yields, county averages; highest in 16 years (1920-1937 except 1921, 1922). Bushels per acre.

Average Wheat Yields

Figure 11 presents the county average yields of wheat for the average of 18 years, 1920-1937. The length of this period is significant because wheat yields vary widely in Indiana. This map shows that in a large northeastern and a small northwestern area yields average from 18 to 19.5 bushels, whereas in most southern counties the average is less than 14 and in three is less than 12. The large northeastern area with especially high yields is the one in which the acreage devoted to wheat has increased. In the counties where an exceptionally large proportion of the land is devoted to wheat, the yields are not large, however. This suggests that in those sections considerable land ill-adapted to wheat is sown to it or all of it is not as well cared for as is most of the wheat in the north.

Maximum and Minimum Wheat Yields

Figure 12 shows the greatest county average wheat yield per acre harvested from 1920-1937 (except 1921, 1922, for which strictly comparable data are not available). It discloses that in the best year average yields of 30-33 bushels were obtained in seven central counties but that even in their best year eight northern and nine southern counties received less than 22 bushels, Crawford with 20 being the lowest. The eastern counties fared better than the western ones. For the state as a whole, the average yield was 25.9 bushels in 1931, 21 in 1918, 20.7 in 1906, and 20.0 in 1926.

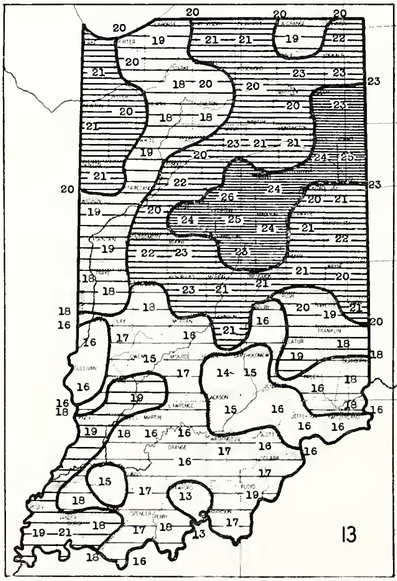

Fig. 13. Wheat: Yields in good years. In the best two years in a decade, even better county average yields are received. Bushels per acre.

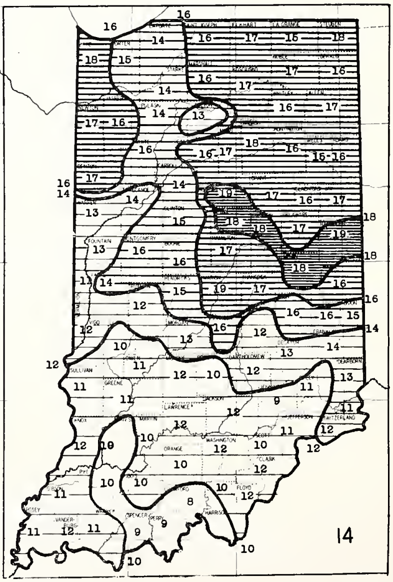

Fig. 14. Wheat: Yields in even a poor year. Only the poorest two years of a decade have lower county average yields. Bushels per acre.

A map, not published, of the smallest county average yields during the 16 years considered in Figure 12 discloses that in poor years central Indiana, except some western counties, had yields of about one-half greater than those received in many southwestern or northern counties and twice as great as Pike, Gibson, Posey, Parke, DeKalb, Cass, LaGrange, and Kosciusko counties, which had averages of only six bushels per acre. Several other southwestern counties had averages of only seven bushels, namely, Harrison, Crawford, Orange, Spencer, Clay, and Vigo, as did also five northern counties, Lake, Pulaski, Fulton, Marshall, and Noble. For the state as a whole, the average wheat yield was only 5.3 bushels in 1900, 8.0 in 1912, and 9.0 in 1896.

Normal Range In Yields

The maximum and minimum yields of record suggest the limits, but from a practical point of view it is even more desirable to know the normal range in yield. Figure 13 shows the yield that can reasonably be expected in a good year. Only the best year in a decade has appreciably larger county averages. This map discloses that in good years wheat yields of 20 bushels per acre are received in the northeastern quarter of the state, the central part of which area receives averages of 23 bushels per acre. On the other hand, all of southern Indiana received less than 20 bushels, much of it less than 18 and ten counties less than 16 bushels.

Figure 14 discloses the yields which may be expected in even poor years but not the very poorest of a decade. In only the three worst years of 15 (1923-1937) was the yield smaller than is shown in this map. It discloses that 16-bushel yields can quite confidently be expected even in poor years in the northeastern quarter of the state and in four northwestern counties but that only one southern county receives yields greater than 12 bushels in such a year. although six receive averages of less than 10 bushels.

Distribution of Oats

Three-fourths of Indiana's counties have devoted for the average of the past decade 10,000 acres or more to oats. The exceptions are in a wide belt parallel with the Ohio River, extending from Gibson to Union county with a short northward extension in central-southern Indiana. Many northern counties devote 30,000 or more acres to oats, and four northwestern counties (Benton, White, Jasper, and Newton) devote from 50,000 to 78,000 acres. The counties with smallest acreages, (aside from the small Fayette, Union, Ohio, Floyd, and Scott counties) are Brown 2,500, Martin 4,000, Clark 4,500, and Jennings 4,500.

Figure 15 discloses that in the southern half of the state less than one-tenth of the land is sown to oats on the average; in the northern half only the northeastern counties have less than one-tenth of their land thus used, and most counties have one-eighth or more of their land in oats. Two large areas, one at the east and the other at the west, have 15% or more of their land in oats; four western counties have more than 20% in oats and Benton County, 30%. At the other extreme, eleven

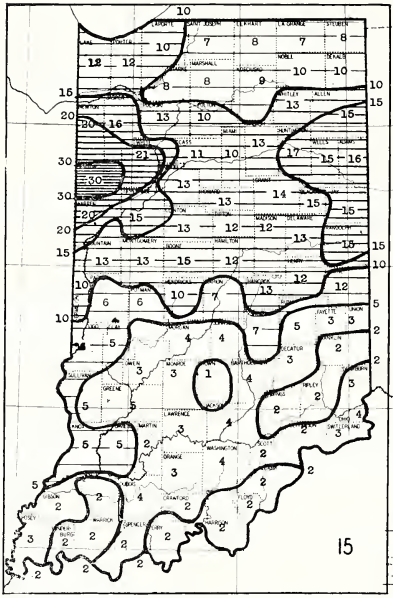

Fig. 15. Oats: Percentage of total land area which is sown to oats (10 year average).

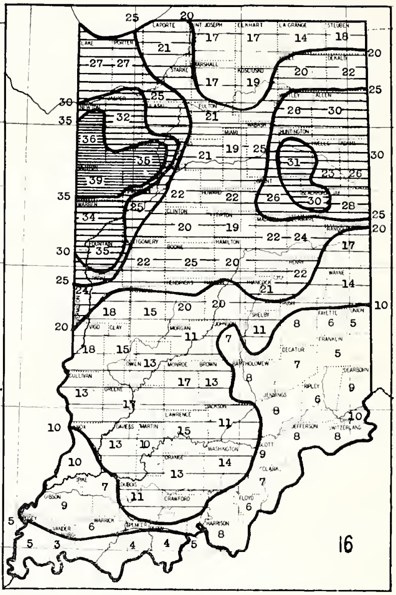

Fig. 16. Oats: Percentage of cropland sown to oats (10 year average).

southern counties have less than 2% of their land area in oats. Brown County with 1.2% has least.

Figure 16, of the percentage of the cropland which is sown to oats, discloses that oats occupy less than one-tenth of such land in the southeast, less than 5% in the extreme south, but more than a quarter of such land in large areas in the northwest and northeast. Benton County leads with 39% of its cropland in oats for the average of a recent decade.

Yield of Oats

The yield of oats varies widely in Indiana. For the entire state it has varied since 1887 from 13.5 bushels per acre in 1934, 17 in 1933, 17.5 in 1890, to 42 in 1917 and 1918, 41 in 1920, and 40 in 1912. The average yield for the state as a whole for 1887-1934 is 29.8 bushels per acre. Figure 17 shows the average yields by counties for the 15 years, 1920-1934. It discloses that in the northeastern quarter yields of 29 or more bushels were average; in most of southern Indiana yields were less than 23 and in seven counties 21 or less.

Figure 18 shows the maximum yield of oats during twelve recent years. During this period no one of the exceptionally favorable seasons for oats is included, and hence the maxima shown are not the highest yields ever received. Nevertheless, the period included two years with a high state average (37 bushels), and hence the maxima shown on this map presumably approach the all-time high. Figure 18 discloses that in the best year county average yields of 45 bushels per acre or more were received in seven counties in the eastern half of the state with yields of 40 to 45 received in about 25 other counties, all in the northeast two-thirds of the state. In most of southern Indiana the largest county averages were less than 35 bushels per acre and in four counties, chiefly in the southeast, less than 30 bushels.

In the poorest year for oats, yields of 15 bushels per acre or less were received in most counties.[6]

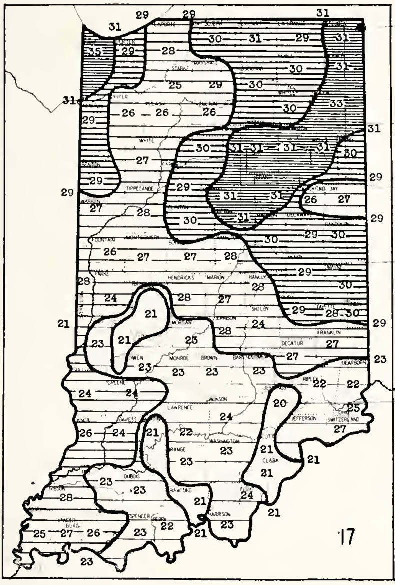

Fig. 17. Oats: Average yields, county averages for a recent 15 year period. Bushels per acre.

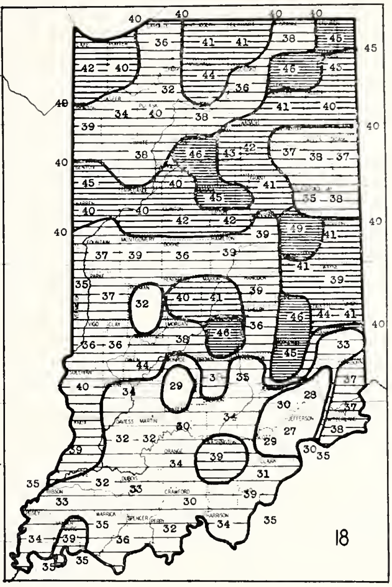

Fig. 18. Oats: Maximum yields, county average, 1923-1934. Bushels per acre.

Conclusions

The distribution of corn, wheat, and oats over Indiana is far from uniform, despite the fact that all three are important in each of the 92 counties. Differences in the proportion of the total land area and of the cropland thus used vary somewhat systematically. Corn occupies nearly or fully one-half of the cropland in all but the most northern elevated and sometimes too cool counties. Wheat occupies a large share of the land of the section with mildest winters because the wheat is winter wheat. Oats are least extensive along the state's southern border where hot weather often comes too early to permit proper development in the spring (the oats are spring sown). Oats are most extensive, in rotation with corn, in the northwestern part of the state.

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[6] Acknowledgments: Assistance in making the numerous calculations was received from three students working for the N. Y. A., especially James Hyndman and Alice Rosenthall. The maps were drafted with the aid of a grant from the Graduate School of Indiana University.

Relative abundance of land devoted to these crops does not correlate closely with average yields. Corn occupies more than half of the cropland in many counties which have a relatively low yield. Similarly, wheat is most extensively sown in one of the less productive areas; conversely, wheat is distinctly less extensive in several counties which have above average yields. Likewise, oats yield better in the eastern than in the western half of the state but are more widely grown in the western half.

The maps of non-average yields throw light upon the contrasts from year to year in the yields and are helpful in understanding certain aspects of the distribution. The distribution of these crops, however, reflects several influences aside from yields, particularly the facts that: (a) no better crop is readily available; (b) the requirements for labor of these crops do not conflict badly, and hence they are often grown so that the farmer is occupied at periods when otherwise there would be little to do; (c) the possibility of receiving a big yield. The maps of maximum yields indicate this inviting possibilty.

SECTION ON MATHEMATICS

Chairman: J. E. DOTTERER, Manchester College

The attendance at the Mathematical Section showed a marked increase over that of previous years. Professor P. D. Edwards, of Ball State Teachers College, was elected chairman for 1939.

ABSTRACTS

Invariant subspaces lying in algebraic hypersurfaces of a certain class. D. R. SHREVE, Purdue University.—The paper considers a class of algebraic hypersurfaces representing a generalization of the Clebsch Diagonal Surface and the Segre Cubic Variety. The subspaces discussed are generalizations of the 15 diagonal lines and the 15 planes, respectively lying in these two surfaces. The treatment is algebraic.

Concerning an equality of Landau. A. C. SCHAEFFER and R. J. DUFFIN, Purdue University.—A theorem of Landau relates the bound of a function and the bound of its first two derivatives. It is shown here how inequalities of this type may be sharpened.

Entire functions of exponential type. R. J. DUFFIN and A. C. SCHAEFFER, Purdue University.—Suppose f(z) is an entire function of exponential type. A sufficient condition that f(z) be bounded for real values of z is found.

On flat-sphere geometry. R. H. DOWNING, Purdue University.—In previous papers a partial development of flat spread-sphere geometry in non-Euclidean odd dimensional space has been given. This paper is concerned principally with the surface elements formed when two flats of (n-2)/2 dimensions, which are tangent to the absolute surface, intersect in a line. The corresponding elements in an image space of the same dimensions, obtained under the general flat-sphere transformation, are also discussed.

The most dense lattice-form distribution of congruent convex solids. PAUL M. PEPPER, University of Notre Dame.—Various attempts have been made to find that arrangement or those arrangements of certain simple congruent convex solids for which the ratio of space filled to all space is as great as possible, for example, the densest packing of spheres in space. When the convex solid lacks the complete symmetry of the sphere, this problem becomes most difficult and apparently impossible of solution except in certain special cases. There is, however, a quite similar problem wherein the arrangements considered are limited to those for which corresponding lines in the congruent solids are kept parallel. This paper concerns itself with the results which have been obtained for such homothetic arrangements.

Note on Linkages

M. H. AHRENDT, Ball State Teachers College

The article "Linkages", by Mr. Hilsenrath, in the October 1937 issue of the *Mathematics Teacher*, is one of special interest since it deals with a subject not ordinarily emphasized in mathematics courses. It opens a new and interesting study to the student with ramifications carrying over into many related fields of practical and theoretical work. The article is of greatest interest if the reader actually constructs the linkages described and observes their operation. The construction of these linkages, however, presents some problems because of a few slight inaccuracies and omissions in the article.

The most serious omission appears to occur in the discussion of the Peaucellier Conicograph. It is stated in the article that when the length of the

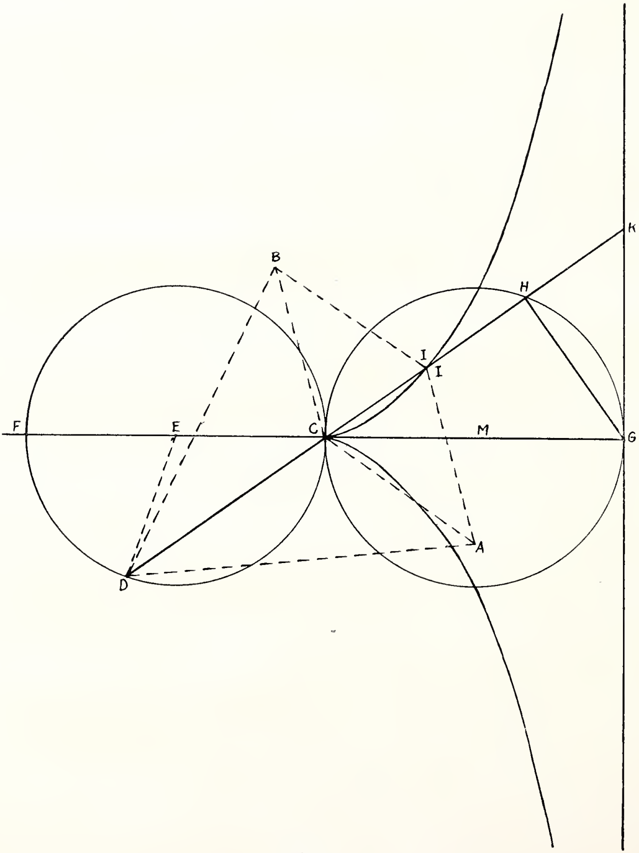

Fig. 1.

radius bar ED is equal to the distance between E and C, then the curve described by I is a Cissoid of Diocles. This is a necessary but not a sufficient condition. Evidently there are an infinite number of positions of E that will enable us to have a radius bar $ED=EC$ (Fig. 1), but in only one of these positions will the cissoid be drawn. The condition that Mr. Hilsenrath has omitted is this:

$$\mathrm{EC} = \tfrac{1}{2}\sqrt{\overline{\mathrm{DA}}^2 - \overline{\mathrm{AI}}^2}$$

As pointed out by Mr. Hilsenrath, the most important property of the Peaucellier Cell (used in this linkage with C as the fixed point instead of D) is that the product $DC \cdot DI = \overline{DA}^2 - \overline{AI}^2 =$ a constant. When the rhombus is collapsed so that C and I coincide, then we readily see that

$$(1) \qquad \mathrm{DC} \cdot \mathrm{DI} = \overline{\mathrm{DC}}^2 = \overline{\mathrm{FC}}^2 .$$

FC then equals $2EC$, and is the diameter of the circle which the point D must follow if the linkage is to draw the cissoid.

Now let another circle with center M be drawn tangent to the first circle at C and with diameter $CG=FC$. Then

$$\mathrm{CH} = \mathrm{DC}.$$

Also
$$\mathrm{DI} = \mathrm{DC} + \mathrm{CI}.$$

Substituting these values in equation (1) we get

$$(2) \qquad \mathrm{CH}\ (\mathrm{CH} + \mathrm{CI}) = \overline{\mathrm{CG}}^2 .$$

The question now is, does this last equation satisfy the requirements of the cissoid? Let GK be tangent to the circle at G. Lay off CI' equal to HK. Then by definition the locus of the point I' is a cissoid. By using the triangles CHG and CKG, we note the following facts:

$$\angle \mathrm{HCG} = \angle \mathrm{KCG}$$
$$\angle \mathrm{CHG} = \angle \mathrm{CGK}$$
$$\therefore \triangle \mathrm{CHG} \sim \triangle \mathrm{CKG}$$
$$\therefore \frac{\mathrm{CH}}{\mathrm{CG}} = \frac{\mathrm{CG}}{\mathrm{CK}}$$

or
$$\mathrm{CH} \cdot \mathrm{CK} = \overline{\mathrm{CG}}^2 .$$

But
$$\mathrm{CK} = \mathrm{CH} + \mathrm{HK} = \mathrm{CH} + \mathrm{CI}'$$

$$(3) \qquad \therefore \mathrm{CH}\ (\mathrm{CH} + \mathrm{CI}') = \overline{\mathrm{CG}}^2 .$$

From a comparison of equations (2) and (3) it is evident that I and I' must be the same point, and, therefore, when the linkage is deformed, the point I describes the cissoid.

The discussion of Bricard's Straight-Line Motion also appears to contain some slight inaccuracies. The article states that the length $DB=EC=\frac{a^2}{b}$, and that $DE=\frac{ac}{b}$. But these two conditions are evidently impossible from the appearance of the linkage and they do not seem to fit the proof needed to establish the theory of the instrument. The correct ratios appear to be these: $DB=EC=\frac{b^2}{a}$, $DE=\frac{bc}{a}$.

Mr. Hilsenrath also states that the proof for this linkage is based on the theorem that a straight line is the locus of a point which moves so that the difference between the squares of its distances from two fixed points is a constant. The theorem best applied here, however, seems to be a much simpler

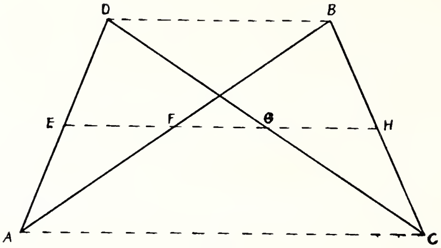

Fig. 2.

one from elementary geometry, namely: The locus of a point equidistant from two fixed points is a straight line which is the perpendicular bisector of the line joining the fixed points. Using this theorem and the ratios given above, the proof for this linkage is quite simple. By drawing the lines FA, DA, etc., we form triangles. It may then be proved in several ways, using congruency or similarity of triangles that $FA = AG$. According to the above theorem, then, the locus of A is a straight line.

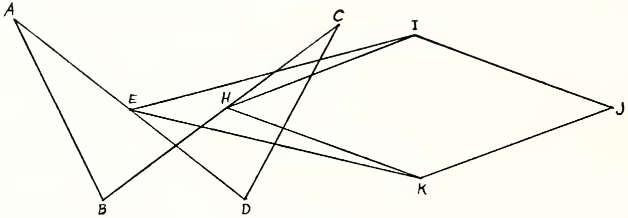

Fig. 3

The Peaucellier Cell is of interest, of course, primarily because it was the first known means of drawing a straight line without the use of a straight edge. The Cell, however, demonstrates so effectively the basic facts of the geometry of inversion that one seems to be wasting a valuable opportunity if he does not construct this linkage so as to make it do more than merely illustrate the straight line. After we have constructed our Cell, then the radius of the circle of inversion of the Cell is $r = \sqrt{\overline{DA}^2 - \overline{AI}^2}$. This circle may be drawn on the board, and it helps immeasurably in understanding the definition of inversion. Now if we let C or I follow a straight line through D, it becomes evident that any line through the center of inversion is its own inverse. As indicated by Mr. Hilsenrath, a circle through D inverts into a straight line, and a circle not through D inverts into a circle. It is possible, however, to fix the center and radius of this second circle so that both C and I describe complete circles instead of arcs, and this illustrates the theorem vividly. Also it is worth while to arrange that C can draw still a third circle orthogonal to the circle of inversion. Then we note that I follows the same circle; that is, a circle orthogonal to the circle of inversion is its own inverse.

As Mr. Hilsenrath effectively points out, the nine linkages described in his article do not exhaust the subject of linkages. There are a number of other linkages which are sufficiently simple that they might well be added to a collection. Two of these are here described.

It is interesting to note that the Peaucellier Cell is not the only instrument which has the property that the product of the distances of two points from a third point is a constant. A simpler arrangement is the inversor by Hart illustrated in Figure 2. *ABCD* is a contra-parallelogram and *E*, *F*, *G*, and *H* are the mid-points of the sides. Now it is evident from the figure that:

$$EG = FH = \tfrac{1}{2}AC$$
$$EF = GH = \tfrac{1}{2}DB$$

It is also evident that *A*, *D*, *B*, and *C* are concyclic. Therefore, by Ptolemy's theorem,

$$AC \cdot DB + AD \cdot BC = AB \cdot DC$$

But $$AD = BC \text{ and } AB = DC$$

$$\therefore AC \cdot DB = \overline{AB}^2 - \overline{AD}^2$$
$$\tfrac{1}{2}AC \cdot \tfrac{1}{2}DB = \tfrac{1}{4}(\overline{AB}^2 - \overline{AD}^2)$$
$$\therefore EG \cdot EF = \tfrac{1}{4}(\overline{AB}^2 - \overline{AD}^2) = \text{a constant}$$

Therefore, if we fix the point *E*, and *F* describes a circle through *E*, then *G* draws a straight line. That is, exactly the same things that are accomplished by the Peaucellier Cell are also accomplished by this instrument. It is not actually necessary that *E*, *F*, *G*, and *H* be the mid-points of the sides of the contra-parallelogram. It is only necessary that they lie on a straight line parallel to *AC*.

An interesting variation of the above linkage is had by fixing the side *AD* and letting *H* be the marking point. A variety of curves can then be drawn, depending on the ratio between the sides *AD* and *AB*. If we now attach a Peaucellier Cell to the linkage so that the point connecting the long sides of the Cell is fixed at *E* and the inner point of the rhombus is attached to *H*, then the outer point of the rhombus evidently draws the inverse of the curve described by *H*. (As shown above, a second contra-parallelogram could be used instead of the Cell with the same results.) A very interesting special case of this linkage is represented in Figure 3. Let the contra-parallelogram be constructed so that $AD : AB :: \sqrt{2} : 1$. *AD* thus becomes the long side, and *E* and *H* are the mid-points of *AD* and *BC* respectively. Let *AD* be the fixed side. It can be proved by analytical geometry that when this linkage is deformed the locus of *H* is a lemniscate. Now if a Peaucellier Cell is attached to the points *E* and *H*, then *J* describes the inverse of the lemniscate. That is, *J* describes an equilateral hyperbola.

The Solution of Bernoulli's Differential Equation by Means of Integrating Factors

WILL E. EDINGTON, DePauw University

The solution of differential equations by means of integrating factors is seldom treated very satisfactorily in textbooks for beginners. The probable reason is that the theoretical development of integrating factors involves a linear partial differential equation. However, students beginning differential equations are, or should be, familiar with elementary partial differentiation, and this assumption will be made in the developments given here. The purpose of this paper is to point out the unity of method and insight into the nature of integrating factors that may be obtained by elementary methods and to secure the solution of Bernoulli's differential equation by means of an integrating factor as a fine illustration of the method.

The usual form of the first order differential equation is

$$Mdx+Ndy=0, \tag{1}$$

where M and N are functions of either x or y or both. In general the equation is not exact, and, although theoretically the number of integrating factors is infinite, the determination of even one such factor is frequently beyond the powers of the beginner, even if considered practicable. However, suppose $Z(x,y)$ to be an integrating factor of $Mdx+Ndy=0$. Then

$$ZMdx+ZNdy=0 \tag{2}$$

is exact, and the condition for exactness

$$\frac{\partial(ZM)}{\partial y}=\frac{\partial(ZN)}{\partial x} \tag{3}$$

is satisfied and one readily obtains

$$Z\left(\frac{\partial M}{\partial y}-\frac{\partial N}{\partial x}\right)=N\frac{\partial Z}{\partial x}-M\frac{\partial Z}{\partial y}$$

which is of the form $Pp+Qq=R$, the first order partial differential equation.

By assuming Z to be a function of x only, or of y only, or of the form $e^{f(x)}$ or $e^{f(y)}$, one obtains the usual special forms of integrating factors. Thus, for example, consider the linear differential equation $dy+(Py-Q)dx=0$, where P and Q are functions of x only. Multiplying by Z, one has $Zdy+Z(Py-Q)dx=0$. which is now exact, and, because the equation is exact, equation (3) becomes

$$\frac{\partial Z}{\partial x}=\frac{\partial Z}{\partial y}(Py-Q)+PZ.$$

If now Z is assumed to be a function of x only, one has $dZ/Z=Pdx$, whence $Z=e^{\int Pdx}$, the well known form of the integrating factor. As another illustration consider the equation $y(2xy+e^x)dx-e^x dy=0$. Since y appears to a higher power than the first and since e^x appears, assume $Z=e^{f(x)}y^m$. Then

$$e^{f(x)}y^m(2xy+e^x)dx-e^{f(x)+x}y^m dy=0$$

is exact, and applying equation (3) and simplifying, one has

$$(m+2)2xy+e^x[m+2+f'(x)]=0$$

identically, whence $m+2=0$, and $m=-2$, and $f(x)$ is constant. Accordingly $Z=y^{-2}$ is the integrating factor. As another illustration consider the equation

$$x^2y\ dy+(y^2-x^4)dx=0.$$

Let $Z=e^{f(x)}y^n$. Then

$$e^{f(x)}y^{n+1}x^2dy+e^{f(x)}(y^{n+2}-x^4y^n)dx=0$$

is exact and equation (3) becomes, after simplification,

$$y^2[2x+x^2f'(x)-(n+2)]+nx^4=0.$$

Therefore $n=0$, and $2x+x^2f'(x)-2=0$, whence $f'(x)=2/x^2-2/x$, $f(x)=-2/x-2\ logx$, and $Z=e^{-\frac{2}{x}}/x^2$.

As a final illustration consider

$$xyt^2(3y\ dx+x\ dy)-(2y\ dx-x\ dy)=0.$$

Let $Z=x^my^n$, whence, upon multiplying through by Z, applying equation (3), and simplifying, one has

$$(3n-m+7)xy^2-(2n+m+3)=0,$$

and $3n-m+7=0$, $2n+m+3=0$. Solving, one finds $m=I$, $n=-2$, and $Z=x/y^2$.

Bernoulli's equation is

$$dy+(Py-Qy^n)dx=0,$$

where P and Q are functions of x only. Assume $Z=e^{f(x)}y^k$. Multiplying the equation by Z, applying equation (3) and simplifying, one has

$$f'(x)=k(P-Qy^{n-1})+P-nQy^{n-1}.$$

Separating the variables,

$$[(k+I)P-f'(x)]\big/_{Q}=(k+n)y^{n-1}.$$

The left member of this last equation is a function of x only, and the right member is a function of y only. Hence $k+n=0$, whence $k=-n$, and then

$$(I-n)P-f'(x)=0,$$

whence $f(x)=\int(I-n)Pdx$, and $Z=y^{-n}e^{\int(1-n)Pdx}$. Thus one may write down the integrating factor immediately whereas the usual method of solution is to make a substitution that will reduce the equation to the linear form.

Symmetric Jacobi Polynomials

MAJOR ALLEN P. COWGILL, U. S. Army, Retired,
Syracuse University

1. Introduction. It is felt advisable to make more readily available the formulas one finds necessary in working with series of symmetric Jacobi polynomials. These polynomials are denoted by $F(n+p,-n,(p+1)/2,(1-x)/2)$, $G_n(p,(p+1)/2,(1-x)/2)$, $X_n^{\frac{p-1}{2},\frac{p-1}{2}}(x)$ and, more recently, $X_n^{\frac{p-1}{2}}(x)$. In mathematical literature most developments are made with two members of the family, Tschebychef (trigonometric) polynomials, $p=0$, and Legendre polynomials, $p=1$. Legendre polynomials are easiest to use. Developments can and should be made for the family rather than particular members in certain cases.

2. History. Gauss[1] was interested in the Hypergeometric Series

$$F(\alpha,\beta,\gamma,x)=1+\frac{\alpha\cdot\beta}{1\cdot\gamma}x+\frac{\alpha(\alpha+1)}{1\cdot 2}\,\frac{\beta(\beta+1)}{\gamma(\gamma+1)}x^2+\cdots\cdot$$

$$(1)\qquad \cdots+\frac{\alpha(\alpha+1)\cdots\cdot(\alpha+k-1)}{1\cdot 2\cdots\cdots k}\cdot\frac{\beta(\beta+1)\cdots\cdots(\beta+k-1)}{\gamma(\gamma+1),\cdots\cdots(\gamma+k-1)}x^k+\cdots\cdot$$

as the solution of the differential equation

$$(2)\qquad x(1-x)y''+[\gamma-(\alpha+\beta+1)x]y'-\alpha\beta y=0.$$

Jacobi[2] discovered that this series terminates itself if one of the elements α or β, which enter the series symmetrically, is a negative integer. The polynomials are solutions of the differential equation, but can also be obtained by successive differentiation of a function of x.

$$(3)\qquad \begin{aligned} &F(\alpha+n,-n,\gamma,x)\\ &=1+\frac{(\alpha+n)(-n)}{1\cdot\gamma}x+\frac{(\alpha+n)(\alpha+n+1)}{1\cdot 2}\cdot\frac{(-n)(-n+1)}{\gamma(\gamma+1)}x^2+\cdots\cdots\\ &\cdot\cdot+\frac{(\alpha+n)(\alpha+n+1)\cdots(\alpha+2n-1)}{1\cdot 2\cdot 3\cdots\cdot n}\cdot\frac{(-n)(-n+1)\cdots(-1)}{\gamma(\gamma+1)\cdots(\gamma+n-1)}x^n.\end{aligned}$$

$$(4)\qquad \begin{aligned} &F(\alpha+n,-n,\gamma,x)\\ &=\frac{x^{1-\gamma}(1-x)^{\gamma-\alpha}}{\gamma(\gamma+1)\cdots\cdot(\gamma+n-1)}\,\frac{d^n}{dx^n}\,x^{n+\gamma-1}(1-x)^{\alpha+n-\gamma}.\end{aligned}$$

Darboux[3] and Abramescu[4] wrote extensive articles on Jacobi polynomials. Darboux's article was the source of most of the formulas in this paper. He it was who first extended the field of orthogonal polynomials from the real axis to the complex plane.

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[1] Gauss, 1812. Disquisitiones generales Circa Seriem Infinitam, Werke, 3:127.

[2] Crelle's Journal, 1859. 56:149-165.

[3] Mémoire sur l'approximation des fonctions de très grands nombres. Journal de Math. 1878. 4:5-60, 377-416.

[4] Sulle serie di polinomi di una variable complessa. Le serie di Darboux. Annali di Mathematica. 31:207-249.

3. Transformation for Symmetric Polynomials. The condition $\alpha - \gamma = \gamma - 1$, where the difference between α and γ is equal to the difference between γ and *1*, and the transformation of x to $(1-x)/2$ gives "symmetric" Jacobi polynomials. They cause

1. Alternate coefficients to become zero, thereby eliminating much work in calculations.
2. The recursion formula to include only terms of first degree in n. This was necessary in the proof of Cesàro summability of $\sum_{1}^{\infty} a_n n^p X_n$, where p is a positive integer[5].
3. The range to be $-1 < x < 1$, instead of $0 < x < 1$.

For Tschebychef polynomials $\alpha = 0$, $\gamma = \frac{1}{2}$, the difference being $\frac{1}{2}$. For Legendre polynomials $\alpha = \gamma = 1$, the difference being *0*.

There is no reason why α cannot be greater than *1*, ie. $\alpha = 3$, $\gamma = 2$, or $\alpha = 5$, $\gamma = 3$. The only rigid condition the writer finds is $\alpha > -1$.

4. The Differential Equation. The original hypergeometric differential equation of Gauss (2) is transformed to

$$(1-x^2)X_n'' - [(p+1)x]X_n' + (p+n)nX_n = 0. \tag{5}$$

In modern notation $\alpha = p$ and $\gamma = (p+1)/2$, one choosing any $p > -1$. Unless explicitly stated otherwise the formulas throughout the remainder of the paper, including (5), all contain p, X_n denotes $X_n^{\frac{p-1}{2}}(x)$, and x is confined to the range $-1 < x < 1$.

5. The Recursion Formula. From the recursion formula

$$xX_n = \frac{n+p}{2n+p}X_{n+1} + \frac{n}{2n+p}X_{n-1} \tag{6}$$

one can get any set of polynomials by taking $X_0 = 1$, $X_1 = x$, and assuming a value of $p > -1$.

The polynomials can be obtained from (3) or (4), letting $x = (1-x)/2$, $\alpha = p$ and $\gamma = (p+1)/2$. They are also obtained from the generating function.

6. The Generating Function. Brenke's method[6] of deriving the generating function is based on the Lagrange expansion formula[7].
Putting the differential equation (5) in the form

$$\frac{1-x^2}{p+1}X_n'' - xX_n' + \frac{p+n}{p+1}nX_n = 0,$$

one substitutes the coefficient of X_n'' for $\phi(y)$, changing x to y, in the equation $y = x + t\phi(y)$ and obtains

$$y = x + t\frac{1-y^2}{p+1}. \tag{a}$$

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[5] Cowgill, 1935. On the summability of a certain class of series of Jacobi Polynomials. Bull. Am. Math. Soc. 41: 541-549.

[6] On polynomial solutions of a class of linear differential equations of the second order. Bull. Am. Math. Soc. 36:77-84, 82. 1930.

[7] Goursat-Hedrick, 1904. Mathematical Analysis. Vol. 1, par. 189.

Differentiating partially with respect to *x*

$$\frac{\partial y}{\partial x}=1+\frac{t}{p+1}(-2y)\frac{\partial y}{\partial x} \quad , \quad \frac{\partial \gamma}{\partial \chi}=\frac{1}{1+\dfrac{2ty}{p+1}}$$

From (a)

$$\frac{ty^2}{p+1}+y-\left(x+\frac{t}{p+1}\right)=0.$$

Solving by the quadratic formula and making the transformation $t=\frac{p+1}{2}t$,

$$y=\frac{-1\pm\sqrt{1-2tx+t^2}}{-t}.$$

$$\frac{\partial y}{\partial x}=\frac{1}{1-ty}=\frac{1}{\sqrt{1-2tx+t^2}}.$$

Substituting the "characteristic function"

$$\rho=(p+1)(1-x^2)^{\frac{p-1}{2}}$$

in Brenke's expression for the generating function,

$$\text{(7)} \qquad \psi(x,t)=\frac{\rho(y)\,\partial y}{\rho(x)\,\partial x}=\frac{(p+1)(1-y^2{}^{\frac{p-1}{2}}}{(p+1)(1-x^2)^{\frac{p-1}{2}}}\,\frac{1}{\sqrt{1-2tx+t^2}}$$

$$=\left[\frac{t^2-(1-2\sqrt{1-2tx+t^2}+1-2tx+t^2)}{t^2\,(1-x^2)}\right]^{\frac{p-1}{2}}\frac{1}{\sqrt{1-2tx+t^2}}$$

$$=\frac{\left[\dfrac{4}{1-x^2}\,(2tx-2+2\sqrt{1-2tx+t^2})\right]^{\frac{p-1}{2}}}{(2t)^{p-1}\sqrt{1-2tx+t^2}}$$

$$=\sum_{r=0}^{\infty} a_r X_r t^r \ ,$$

where

$$a_n=\frac{(p+1)(p+3)\cdot\cdot\cdot\cdot\cdot(p+2n-1)}{2^n\ n!}$$

$$=\frac{\Gamma\left((p+1)/2+n\right)}{\Gamma\left((p+1)/2\right)\Gamma(n+1)}=0\left(n^{\frac{p-1}{2}}\right).$$

$$X_n=0\left(n^{-\frac{p}{2}}\right),\ \text{so}\ a_nX_n=0\left(n^{-\frac{1}{2}}\right)$$

$$X_n(1)=1,\ X_n(-1)=(-1)^n\,[8]$$

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[8] This is shown by using equations (1) and (4), Darboux, loc. cit., p. 377, and making the transformation $x=(1-\xi)/2$, $x=0$ corresponding to $\xi=1$ and $x=1$ corresponding to $\xi=-1$, $\alpha-\gamma=\gamma-1$.

One also has the relation[9]

$$(8)\qquad \sum_{r=0}^{\infty} \frac{\Gamma(r+p)}{\Gamma(p)\,\Gamma(r+1)} X_r t^r = \frac{1}{(1-2tx+t^2)^{\frac{p}{2}}} \qquad (0<t<1).$$

Differentiating both sides of (8), multiplying throughout by *2t* and adding to (8), one gets

$$\sum_{r=0}^{\infty} \frac{\Gamma(r+p)}{\Gamma(p)\,\Gamma(r+1)} (2r+p)\, X_r\, t^r = \frac{p(1-t^2)}{(1-2tx+t^2)^{\frac{p}{2}+1}}$$

which one can write in the form

$$(9)\qquad \sum_{r=0}^{\infty} \frac{\Gamma(r+p)}{\Gamma(r+1)} (2r+p)\, X_r\, t^r = \frac{\Gamma(p+1)}{(1-2tx+t^2)^{\frac{p}{2}}} \; \frac{1-t^2}{1-2tx+t^2}.$$

Let $p=0$ and one obtains the special generating function for the Tschebychef polynomials

$$(10)\qquad \sum_{r=0}^{\infty} 2[X_r^{-\frac{1}{2}}(x)]\, t^r = \frac{1-t^2}{1-2tx+t^2}, \text{ or}$$

$$\sum_{r=0}^{\infty} T_r(x)(2t)^r = \frac{1-t^2}{1-2tx+t^2} \text{ where } T_n(x) = \frac{1}{2^{n-1}}[X_n^{-\frac{1}{2}}(x)].$$

One can now see that series (9) is the Cauchy product of series (8) and series (10), as well as being the right hand member of the Christoffel-Darboux identity

$$(11)\qquad \frac{\Gamma(n+p)}{\Gamma(p)\,\Gamma(n+1)} (n+p) \frac{X_{n+1}-X_n}{x-1}$$

$$= \sum_{r=0}^{n} \frac{\Gamma(r+p)}{\Gamma(p)\,\Gamma(r+1)} (2r+p) X_r, \text{ when } t=1.$$

7. Symmetric Jacobi Polynomials.

$p=0$, Tschebychef Polynomials.

$X_0(x)=1$	$X_0(\cos\theta)=1$
$X_1(x)=x$	$X_1(\cos\theta)=\cos\theta$
$X_2(x)=2x^2-1$	$X_2(\cos\theta)=\cos 2\theta$
$X_3(x)=4x^3-3x$	$X_3(\cos\theta)=\cos 3\theta$
$X_4(x)=8x^4-8x^2+1$	$X_4(\cos\theta)=\cos 4\theta$

$p=\frac{1}{2}$.

$X_0=1$

$X_1=x$

$X_2=\frac{5}{3}(x^2-\frac{2}{5})$

$X_3=3(x^3-\frac{2}{3}x)$

$X_4=\frac{1}{7}(39x^4-36x^2+4)$

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[9] Cowgill, *loc. cit.*, pp. 543 and 545.

$p=1$. Legendre Polynomials.

$X_0=1$

$X_1=x$

$X_2=\frac{1}{2}(3x^2-1)$

$X_3=\frac{1}{2}(5x^3-3x)$

$X_4=\frac{1}{8}(35x^4-30x^2+3)$

$p=3$.

$X_0=1$

$X_1=x$

$X_2=\frac{1}{4}(5x^2-1)$

$X_3=\frac{1}{4}(7x^3-3x)$

$X_4=\frac{1}{8}(21x^4-14x^2+1)$

$p=5$.

$X_0=1$

$X_1=x$

$X_2=\frac{1}{6}(7x^2-1)$

$X_3=\frac{1}{2}(3x^3-x)$

$X_4=\frac{1}{16}(33x^4-18x^2+1)$

8. **The Orthogonality Property.** In expanding any function of *x* into an infinite series of symmetric Jacobi polynomials it is necessary that the polynomials have the orthogonality property expressed by

$$(12) \qquad \int_{-1}^{1} \rho X_m X_n dx = \begin{cases} 0\ , & m \text{ not equal to } n \\ J_n, & m=n\ , \end{cases}$$

so that the coefficients can be determined.

Brenke's[10]; condition for orthogonality will hold with the polynomial solutions of (5).

The derivation of the characteristic function ρ and Darboux's value of the constant J_n are best explained in detail.

9. **The Characteristic Function** ρ. To explain the derivation of the characteristic function ρ one assumes the differential equation

(b) $\qquad rX_n''+sX_n'+t_nX_n=0$, t_n a function of *n*.

Multiplying (b) by ρ so as to make it "self adjoint", one has

(c) $\qquad \rho rX_n''+\rho sX_n'+\rho t_nX_n=0$, where

(d) $\qquad \frac{d}{dx}\rho r=\rho s=\rho' r+\rho r'$. (b) can now be written

(e) $\qquad \frac{d}{dx}(\rho rX_n')+\rho t_nX_n=0.$

From (d) $\rho' r=\rho(s-r')$. $\frac{\rho'}{\rho}=\frac{s-r'}{r}=\frac{s}{r}-\frac{r'}{r}$.

Multiplying by *dx* and integrating

$$\int \frac{\rho'}{\rho}\, dx=\int \frac{s}{r}\, dx-\int \frac{r'}{r}\, dx\ ,$$

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[10] Brenke, *loc. cit.*, Case 1, pp. 78-79.

$$\log \rho = \int \frac{s}{r}dx - \log r ,$$

$$\log \rho + \log r = \log \rho r = \int \frac{s}{r}dx ,$$

$$\rho r = e^{\int \frac{s}{r}dx} \quad \text{or} \quad \rho = \frac{1}{r}e^{\int \frac{s}{r}dx}$$

Taking the differential equation (5) in the form

$$\frac{1-x^2}{p+1}X_n'' - xX_n' + \frac{(p+n)n}{(p+1)}X_n = 0$$

and comparing it to (b)

$$r = \frac{1-x^2}{p+1} \text{ and } s = -x, \quad \text{so}$$

(13) $$\rho = \frac{p+1}{1-x^2}e^{(p+1)\int \frac{-xdx}{1-x^2}} = (p+1)(1-x^2)^{\frac{p-1}{2}} .$$

Write the "self adjoint" equations for X_n and X_m.

(f) $$\frac{d}{dx}(\rho r X_n') + \rho t_n X_n = 0$$

(g) $$\frac{d}{dx}(\rho r X_m') + \rho t_m X_m = 0 .$$

Multiply (f) by X_m and (g) by X_n. Subtracting, multiplying by dx and integrating[11] one gets

$$(t_m - t_n)\int_{-1}^{1} \rho X_m X_n dx = \int_{-1}^{1} X_m \frac{d}{dx}\left(\rho r \frac{dX_n}{dx}\right)dx - \int_{-1}^{1} X_n \frac{d}{dx}\left(\rho r \frac{dX_m}{dx}\right)dx .$$

Integrating by parts

$$(t_m - t_n)\int_{-1}^{1} \rho X_m X_n dx = \left[X_m\left(\rho r \frac{dX_n}{dx}\right) - X_n\left(\rho r \frac{dX_m}{dx}\right)\right]_{-1}^{1}$$

$$-\int_{-1}^{1} \rho r \frac{dX_n}{dx}\frac{dX_m}{dx}dx + \int_{-1}^{1} \rho r \frac{dX_m}{dx}\frac{dX_n}{dx}dx .$$

As ρr contains the factor $(1-x^2)$ the non-integral term is 0 and $\int_{-1}^{1} \rho X_m X_n dx = 0$ unless $m = n$. This last equation expresses the orthogonality property (12).

10. Derivation of J_n. The writer found it necessary to solve for J_n with the notation of Darboux and general Jacobi polynomials. From Darboux[12] "One has also

$$J_n = \int_0^1 x^{\gamma-1}(1-x)^{\alpha-\gamma} X_n^2 dx$$

$$= \frac{\Gamma(n+1)\ \Gamma^2(\gamma)\ \Gamma(\alpha+n-\gamma+1)}{(2n+\alpha)\ \Gamma(\alpha+n)\ \Gamma(\gamma+n)} \text{ ''.}$$

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[11] Byerly, Fourier's Series. Par. 91, p. 171.

[12] Loc.cit., (44), p. 46 and (13), p. 22,

and

“$$X_n = F(\alpha+n, -n, \gamma, x)$$

$$= \frac{x^{1-\gamma}\,(1-x)^{\gamma-\alpha}}{\gamma(\gamma+1)\,\cdots\cdots\,(\gamma+n-1)}\,\frac{d^n}{dx^n}\,x^{n+\gamma-1}\,(1-x)^{\alpha+n-\gamma}\text{''}.$$

$$\Gamma(\gamma+n) = (\gamma+n-1)\,(\gamma+n-2)\,\cdots\cdots\,(\gamma+1)\,\gamma\,\Gamma(\gamma)\,,$$

so

$$\gamma(\gamma+1)\,\cdots\cdots\,(\gamma+n-1) = \frac{\Gamma(\gamma+n)}{\Gamma(\gamma)}\,.$$

$$J_n = \frac{\Gamma(\gamma)}{\Gamma(\gamma+n)}\int_0^1 [X_n]\left[\frac{d^n}{dx^n}\,x^{n+\gamma-1}\,(1-x)^{\alpha+n-\gamma}\right]dx\,.$$

One applies integration by parts *n* times, where $\int u\,dv = uv - \int v\,du$, letting the polynomial always be *u* and the derivative and *dx* be *dv*. The *uv* term is always zero with the limits *0* and *1*, as it always contains the terms *x* and *(1—x)* to some power. Differentiating X_n, (3), *n* times one finishes with the coefficient of x^n multiplied by *n*!, so

$$\frac{d^n}{dx^n}X_n = \Gamma(n+1)\,\frac{\Gamma(\alpha+2n)}{\Gamma(n+1)\,\Gamma(\alpha+n)}\;\frac{(-1)^n\,\Gamma(n+1)\,\Gamma(\gamma)}{\Gamma(\gamma+n)}$$

$$= (-1)^n\,\frac{\Gamma(\alpha+2n)\,\Gamma(n+1)\,\Gamma(\gamma)}{\Gamma(\alpha+n)\,\Gamma(\gamma+n)}.$$

After *n* integrations by parts

$$J_n = \frac{\Gamma(\gamma)}{\Gamma(\gamma+n)}\,(-1)^{2n}\,\frac{\Gamma(\alpha+2n)\,\Gamma(n+1)\,\Gamma(\gamma)}{\Gamma(\alpha+n)\,\Gamma(\gamma+n)}\int_0^1 x^{\,n+\gamma-1}(1-x)^{\alpha+n-\gamma}\,dx.$$

$$B(m,n) = \int_0^1 x^{m-1}\,(1-x)^{n-1}\,dx = \frac{\Gamma(m)\,\Gamma(n)}{\Gamma(m+n)}$$ [13]

so

$$\int_0^1 x^{n+\gamma-1}(1-x)^{\alpha+n-\gamma}\,dx = \frac{\Gamma(\gamma+n)\,\Gamma(\alpha+n-\gamma+1)}{\Gamma(2n+\alpha+1)}.$$

$$J_n = \frac{\Gamma(n+1)\Gamma^2(\gamma)\,\Gamma(\alpha+n-\gamma+1)}{(2n+\alpha)\,\Gamma(\alpha+n)\,\Gamma(\gamma+n)}\text{, Darboux's result.}$$

Making the transformation to symmetric Jacobi polynomials

(14) $$Jn = \int_{-1}^{1}(p+1)\,(1-x^2)^{\frac{P-1}{2}}\left[X_n^{\frac{P-1}{2}}(x)\right]^2 dx$$

$$= \frac{2^p\,(p+1)\,\Gamma(n+1)\,\Gamma\left(2^{\frac{p-1}{2}}\right)}{(2n+p)\,\Gamma(p+n)}$$ [14].

11. The Derivative Form. Transforming (4) one obtains

(15) $$X_n = \frac{(-1)^n(1-x^2)^{\frac{1-p}{2}}}{(p+1)\,(p+3)\,\cdots\cdots\,(p+2n-1)}\,\frac{d^n}{dx^n}\,(1-x^2)^{\frac{p+2n-1}{2}}\,.$$

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[13] Woods, Advanced Calculus, p. 166.

[14] See Byerly, loc.cit., par. 89, p. 168, for derivation of Jn for Legendre polynomials.

SECTION ON PHYSICS

Chairman: S. E. ELLIOTT, Butler University

All the papers listed in the program and published in full or in abstract form below were read. The attendance was good. Raymond B. Abbott, of Purdue University, was elected chairman of the section for 1939.

ABSTRACTS

Wave motion demonstration. S. E. ELLIOTT, Butler University.—The machine is designed to aid high school and college students in getting a better understanding of both transverse and longitudinal waves. It shows two transverse waves, traveling in the same or in opposite directions, with the resultants back of them. These waves can have any relative amplitude and wave length, but, as constructed, they are equal in all respects and thus cause standing waves when traveling in opposite directions. The machine also shows a longitudinal wave in which the relative phase of successive particles can be changed, showing longitudinal waves of different length. With additional equipment, standing longitudinal waves can also be shown. All the waves can be made to travel as slowly as desired.

On the thermoelastic properties and on the equation of state of rubber. F. E. DART and E. GUTH, University of Notre Dame.—The high reversible elasticity and the anomalous thermoelastic behavior of rubber are explained qualitatively and to a large extent also quantitatively in terms of the molecular structure of rubber without making any arbitrary assumptions. Rubber consists of long chain molecules, which, in the unstretched state, are in a more or less curved form due to the possibility of free rotations around a single C-C bond in the single chains. This curved form is the most probable one according to the statistical interpretation of the second law of thermodynamics. If a stress be applied, these curved molecules will be stretched, thus giving a transition to a less probable state. When the stress is released, the thermal agitation causes a retraction. Rubber elasticity is then analogous to the elasticity of a gas or a liquid. In order to test and develop further this theory, experimental work on the physical properties of natural and synthetic rubber was begun. Our first objective was to obtain the thermal equation of state of rubber, i. e., the dependency of the stress upon temperature and extension. The thermal state equation together with the so-called caloric state equation, i. e., the dependency of the specific heat at constant extension upon the temperature and the extension, determines completely the thermodynamics of stretched rubber. It gives the free energy of stretched rubber. A stress-strain apparatus allowing stretching and retracting rubber with a constant speed was used in some preliminary work with different types of rubber. Diagrams are presented which show the reproduceability of the data obtained and the change of the extension-retraction curves, i. e., of the hysteresis hoops, with the number of extensions and temperature. Diagrams for equations of state are shown. For elastically normal substances, e. g., steel, wood, etc., the stress decreases with rising temperature. This shows that in these cases the great elastic force between the atoms or molecules causes the retraction for rubber. This force-mechanism of elasticity is present also. However, in addition to the force-mechanism the statistical mechanism described above contributes to the retraction and can even predominate giving rise to an equation of state according to which the stress increases with rising temperature just as this is the case for a gas.

Proton diffraction by vapors. H. J. YEARIAN, Purdue University.—The methods of electron diffraction in molecular structure analysis are inapplicable to molecules of low molecular weight because of the low scattering power of such molecules. Since protons should be scattered much more strongly than electrons, extensive experiments have been made to investigate their diffraction by molecular vapors. It was found possible to obtain diffraction patterns of carbon tetrachloride but not of lighter molecules. The apparatus used, difficulties encountered, and principal results are discussed.

A fundamental error in wave motion. R. R. RAMSEY, Indiana University.—Since it has been shown that *damped wave* oscillators and *continuous wave* oscillators apparently do not give the same kind of resonance curves, detailed studies have been made of the modes of vibration. When the coupling is close, there are two possible modes of vibration, one stable and the other metastable. The circuit does not oscillate in these two modes at the same time. When the oscillator is started, it always assumes the stable mode; the metastable mode is secured by gradually changing the constants of the circuit. It is shown that a damped wave oscillator produces a band of frequencies, and, since a closely coupled circuit is in resonance for two peak responses, the circuit picks out the two frequencies. This is the reason why it was concluded in the old spark days that coupled circuits produce two frequencies. It is proved definitely that coupled circuits do not produce or manufacture two frequencies. This correction should be applied to modern physics.

Modulation a linear process. R. R. RAMSEY, Indiana University.—It seems to be the opinion of many that modulation is a non-linear process, but it is pointed out that, if the adjustments of the circuits are right, it is a linear process. In a class C amplifier, in which the radio frequency current is directly proportional to the plate potential, we have the products of sine terms, with side bands and no harmonics, when the amplifier is modulated. Modulation can also be produced by non-linear addition, but this always produces harmonics and other undesirable combinations.

The scattering of barytrons. J. F. CARLSON, Purdue University.—The increasing experimental evidence for the existence of a "heavy electron" gives importance to the theoretical calculations of its interaction with matter and radiation based on the various models which have been suggested. Since the explanation of nuclear forces by means of the barytron is best given by the description which uses a vector wave function, the calculations for this model are especially important. Only the elastic scattering will be considered. Elastic scattering may take place by two processes, (a) by the absorption and re-emission of barytrons by nuclear particles, analagous to the Compton scattering of light, (b) by the Coulomb field of a nucleus. The first process has been investigated by Heitler, and the second is considered here. The results show that for low energies the Coulomb scattering is more important than the first process and that for high energies the reverse is true. There are also polarization effects present in the scattering which may be of importance for particles traversing the atmosphere.

The Purdue cyclotron. W. J. HENDERSON, Purdue University.—Since the last report to the Indiana Academy of Science the construction of the Purdue cyclotron has been completed. This paper is a description of the construction of the accelerating chamber and of the adjustments of the magnetic field and oscillator. The magnetic field has been corrected by a special ring shim so that the field is now uniform over an area of 40 cm. in diameter. The oscillator and magnetic fields are tuned at present to produce 4.4 million volt protons, 8.8 million volt deuterons, or 17.6 million volt particles. Experiments are being conducted to adapt the low voltage arc as a source of ions.

On the interaction of high energy electrons with nuclei. EUGENE GUTH, University of Notre Dame.—Interaction of high energy electrons with nuclei can give rise to scattering, pair production, and disintegration phenomena. From the theoretical point of view, the pair production and radiation are equivalent processes. The cross-section for both phenomena can be obtained from the same expression by changing simply the variables. Whereas, the experimental results on radition of electrons above one million electron volts are in accordance with the theories at least in the order of magnitude, the experiments of pair production are contradictory with each other and with the theory also. Nuclei can be disintegrated by fast electrons provided that the energy of the electrons exceeds the binding energy of one of the constituents of the nucleus. The threshold value is only for the beryllium nucleus and the deuteron within the range of electron energies available at present experimentally. The cross-section for the disintegration of the beryllium nucleus was calculated by using both the method of Moller and that of the Fourier analysis. The threshold energy is according to the experiments with gamma rays on the photo-disintegration of beryllium 1.7 MEV. This represents the lowest known threshold energy for any nucleus. The cross-section for the disintegration of Be_4^9 into Be_4^8 and a neutron is according to a very conservative estimate of the quantities entering into the formula 10^{-31} cm^2. This is a thousand times smaller than the observed cross-section for the disintegration of beryllium with gamma rays. Experiments to detect an electroneutronic disintegration are in process using electrostatic generators. High energy electrons can also be used for the excitation of nuclei and for the sounding of the nucleus in analogy to the measurement of molecular distances by X-rays and low energy electrons.

On the preparation of metal surfaces for electron emission studies. EDWARD A. COOMES, University of Notre Dame.—The most important requirement imposed upon filaments used in electron emission studies is that they be absolutely gas-free as far as the surface is concerned. Two methods have been generally employed for obtaining clean surfaces. The first, commonly employed for highly refractory metals, consists simply in heating at high temperatures for long periods of time to rid the body of the filament of absorbed gases and a final high temperature flash to clean the surface of gases adsorbed to it. The second method, used mostly for metals of low melting point, consists in building up the working surface by evaporating onto a base filament from a source of the desired metal. Experimental data in general have shown both of these methods to be inadequate for quantitative studies. A further method is offered in which a working surface is built up on a well outgassed filament by evaporating, not from the supposedly pure metal but from a source containing the metal in chemical combination. It has been found, at least in the case of thorium, that such a source can be made to give off the pure metal and hold the gas apparently in solution in the body of the filament if the proper cycle is followed. This is confirmed by experimental work on secondary emission of electrons from a tungsten surface, coated with thorium evaporated from thoriated tungsten.

Continuous Spectra of H_2 and D_2. HUBERT M. JAMES, Purdue University.—Complete theoretical computations have been made of the continuous spectra of H_2 and D_2 arising from transitions from the lower vibrational levels of the $1s\sigma 2s\sigma\ ^3\Sigma_g$ state to the unstable $1s\sigma 2p\sigma\ ^3\Sigma_u$ state. Spectra have been determined for transitions from each of the vibrational levels separately, and the first reported computations on absolute mean lives of molecular vibrational levels have been made. Relative probabilities of excitation from the ground states of the molecules by electron impact have been estimated, and intensities in the spectra excited by electron impact have been computed for a range of energies of the electrons. The spectra of H_2 and D_2 have the same qualitative character but quite appreciable quantitative differences. In the case of H_2 there is sharp disagreement of the results with the observations of Smith. This apparently arises from errors in Smith's intensity standard and emphasizes the need of a more satisfactory intensity standard in the ultraviolet. Agreement with the observations of Finkelnberg and Weizel is obtained.

On the van der Waals energy of two beryllium atoms. JULIAN K. KNIPP, Purdue University.—The first term in the expansion of the electrostatic interaction of two neutral atoms in powers of *1/R*, where

R is the interatomic distance, is the term in $1/R^3$, the dipole-dipole term. Since isolated atoms have no dipole moments, the effect of this term on the energy of the system is only through the mutual polarization of the atoms, a second order effect first treated quantum mechanically by Wang. The constant u in the van der Waals energy, $-u/R^6$, has been calculated for two beryllium atoms using the Hartree-Fock model for the atoms. Perturbation methods are used based on the complete set of solutions of the Fock single-electron differential-integral equation. These solutions satisfy sum rules which, because of the integral part of the Fock equation, are not in general given by the usual relations. Lower bounds to the interaction expression are obtained by the application of the Schwarz inequality and the use of the sum rules derived. In this way u for two beryllium atoms is found to be about 222 10^{-60} erg cm^6.

The fashioning of perfect ellipsoidal boulders by glacial action. OLIVER E. GLENN, Lansdowne, Pa.—The general principles of the flow of a viscous stream, such as the lower layer of a glacier, are obtained by applying mathematics to some types of boulders which are shaped by the action of streams heavily charged with siliceous sand. In upper New England there have been found numerous granite boulders which are mathematically perfect ellipsoids, each with the principal axes different in length; and many of the hills of Maine are hyperboloids. From these facts the law of flow of the stream which fashioned the boulders is derived, appearing in a typical case as follows:

$$F = \text{Speed} = \frac{S\sqrt{(a^4 \sin^2\theta + b^4 \cos^2 \theta)}}{b^2 \cos^2\theta} .$$

The speed at a given level is thus a function of θ with two parameters, S and a/b, and it may further be generalized to contain three parameters. (The origin of polar coördinates (r, θ) was taken as the center of the conicoid.) Reversing the problem and assuming the law of flow in the form F, the solution of a differential equation of the first order shows that the boulder will be an ellipsoid or hyperboloid. This principle offers an explanation why the Tipton Till Plain is flat while the New England landscape is hilly, as well as a number of other suggestions of possible interest to geologists.

Application of trigonometric interpolation to X-ray analysis. C. LANCZOS and G. C. DANIELSON, Purdue University.—The integral representing the intensity distribution of X-ray diffraction in liquids can be evaluated by the method of trigonometric interpolation instead of approximating the integral by the sum of a large number of terms. This reduces considerably the number of ordinates required in the calculation without decreasing the accuracy. As an example, the diffraction patterns of vitreous selenium and liquid KCL and LiCl, obtained and analyzed by K. Lark-Horovitz and E. P. Miller, have been interpreted. For the curves so far analyzed, 36 ordinates were found to be sufficient. Owing to symmetry properties the Fourier coefficients can be found with a minimum of calculation. This yields directly the value of the distribution function in discrete equidistant points. The value of the function for any intermediate point may then be determined in a simple manner by pure calculation. The resulting curves agree very closely with those obtained by Lark-Horovitz and Miller.

The resonance processes in the disintegration of Boron by protons. Bernard Waldman, University of Notre Dame.—Using protons of energies from 150 kev to 195 kev, the gamma ray and alpha particle yields from a thick boron target were determined simultaneously. The observed resonances occur at the same voltage, to within 1 kev. Yield curves on the alpha particles alone place the resonance voltage at 165 ± 4 kev. The observed half-breadth of 6 kev can be ascribed to energy fluctuations in the ion beam. The experiments were done at New York University in collaboration with R. Waddel, D. Callihan, and W. A. Schneider.

A device for demonstrating the resultant of two concurrent forces. C. O. Pauley, Valparaiso H. S.—Demonstration of apparatus.

The trochoid method of magnetic focusing as applied to a study of pair production by electrons. Robert L. Anthony, University of Notre Dame.—Experimental values of the cross-section for pair production in the field of a nucleus by high speed electrons are in poor agreement at the present time. Skobelzyn and Stepanowa, using a cloud chamber, found a value for this cross-section about one hundred times larger than that for gamma rays of the same energy. Da Silva's work, also done with a cloud chamber, yields a value of 8×10^{-23} cm^2 for lead—about half as large as the value of Skobelzyn and Stepanowa. Benedetti, using the trochoid method of focusing and counters, and Alichanow and coworkers, using magnetic focusing and counters, decided that the value was much smaller, too small to be detected by their methods. Staub concluded the value could not be greater than that for gamma rays. Later, Monadjemi, using the trochoid method, obtained large values of the order of 10^{-23} cm^2. Recently work performed by Feather and Dunworth indicates that the larger experimental values may be correct. The majority of these experimental results are much higher than those predicted by theory and seem to indicate that the cross-section is proportional to Z and not to Z^2. In view of the disagreement between these experimental values, and since a large monochromatic source of high energy electrons is available at Notre Dame, we have decided to attempt a more accurate determination of this cross-section. For this purpose, the trochoid method of focusing will be used. This method is particularly well adapted to the problem since the yield obtained by it is from one hundred to a thousand times larger than that obtainable by ordinary magnetic focusing. The magnet which has been constructed for this purpose and the advantages of the trochoid method are described.

A Method of Measuring the Total Output of Speakers

D. B. GREEN, Ohio University

Routine measurements of speaker output are usually made in a single direction on the axis extending out in front of a speaker. However, the total acoustic output is sometimes desired. Indeed, were it not so hard to obtain, the total output would in most cases be the proper information to publish. In speaker efficiency measurements the total output is required, and in actual practice the listener is seldom in open air, where he would receive the output in a particular direction alone, but he is inside a room, where, by reflection, he is subjected to the total speaker radiation field.

There are several methods for finding this total output. The speaker may be measured out-of-doors by taking the average of a number of measurements on the surface of an imaginary sphere of which the speaker is the center (1). In the reverberation chamber method the speaker is located in a highly reverberant room, and its total output calculated by a single measurement with a microphone placed anywhere in the room on the theory that the acoustic pressure becomes constant regardless of frequency and location in the room (2, 3). Another method is to simulate outdoor conditions by making measurements in a highly absorbing room treated with acoustic materials (4). Bell Telephone laboratories have rotated the microphone at a speed sufficient to eliminate standing waves while making measurements (5). A multiple microphone method employs several microphones placed about the speaker so as to obtain at a single measurement sufficient data to calculate the total output.

In the motional impedance method, the free and blocked impedance of the speaker are found electrically, and the efficiency calculated from these constants (6).

There can be no objection to the outdoor method except its inconvenience. Our experience with the reverberation chamber method shows the presence of standing waves in all enclosures, which shift with changing frequency, rendering the results of no value for showing speaker characteristics. As to sound absorbing rooms, it is very difficult to eliminate reflection even with a foot of hair-felt lining the room. In working with the multiple microphone method, the writer has found that all types of microphones have polarity, so that when connected together they will measure the vector sum of the effective values of the acoustic pressure or velocity at their respective locations and thus give maxima and minima as the frequency is varied, showing a pattern which does not belong to the speaker at all (7). The motional impedance method avoids accoustical measurements but neglects mechanical losses of motion and rates the speaker optimistically.

This paper describes a method of measuring the total output of a speaker which is analogous to the method of measuring the total luminous flux from a lamp by means of a globe photometer. The speaker is placed at the center of a 3-foot globe photometer. A microphone is placed at the small window of the globe and shielded from direct radiation from the speaker so that it receives only sound which has been reflected one or more times from the wall of the globe. A single measurement of the intensity at the window gives a figure which is proportional to the total sound flux emitted by the speaker. The theory may be found in textbooks on illumination (8). The method used to eliminate standing waves in the globe was to wobble the frequency of the oscillator used to drive the speaker, above and below the frequency at which it is set. An analysis was made to determine what variation in frequency was desirable to eliminate the standing waves and yet not be so great as to mask the frequency characteristics of the speaker. The frequency variation necessary to move one loop past the microphone and back was calculated, as this requires the microphone to read the average intensity from loop to loop and should smooth out the pattern.

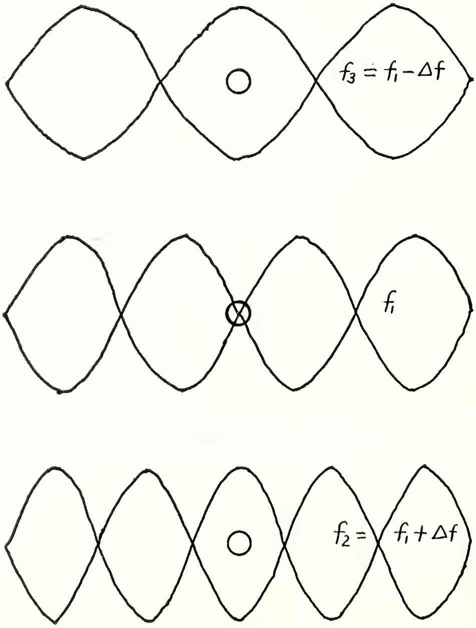

Fig. 1.

In Figure 1 suppose at the middle frequency f_1 there are n_1 half waves in the enclosure. The wavelength $\lambda_1 = \frac{2L}{N_1}$ where L is the length of the enclosure.

$f_1 = \frac{V}{\lambda_1}$ where V is the sound velocity, or $f_1 = \frac{Vn_1}{2L}$

For one more half wave within the globe, $n_2=n_1+1$

$$\lambda_2=\frac{2L}{n_2}=\frac{2L}{n_1+1}$$

$$f_2=\frac{V(n_1+1)}{2L}$$

$$\frac{f_2}{f_1}=\frac{2V(n_1+1)L}{2LVn_1}=\frac{n_1+1}{n_1}=1+\frac{1}{n_1}$$

$$f_2=f_1+\frac{f_1}{n_1}\text{ or }\triangle f=\frac{f_1}{n_1}\text{ but }n_1=\frac{2f_1L}{V}\text{ hence }\triangle f=\frac{f_1V}{2f_1L}=\frac{V}{2L}\text{ a constant.}$$

This shows that to shift the pattern from a node to an antinode in front of the microphone requires a constant frequency increment independent of the original frequency.

Now to see what happens to the pattern when the frequency is decreased by the same increment—

$$f_2=f_1+\frac{V}{2L}\text{ and }f_3=f_1-\frac{V}{2L}$$

$$\lambda_1=\frac{V}{f_1},\ \lambda_2=\frac{V}{f_1+\frac{V}{2L}}=\frac{2LV}{2Lf_1+V}$$

$$\lambda_3=\frac{V}{f_1-\frac{V}{2L}}=\frac{2LV}{2Lf_1-V},\ n_1=\frac{2L}{\lambda_1}=\frac{2Lf_1}{V}$$

$$n_2=\frac{2L}{\lambda_2}=\frac{2Lf_1+V}{V}=n_1+1\quad\text{as was calculated}$$

and $$n_3=\frac{2L}{\lambda_3}=\frac{2Lf_1-V}{V}=n_1-1\quad\text{as we hoped.}$$

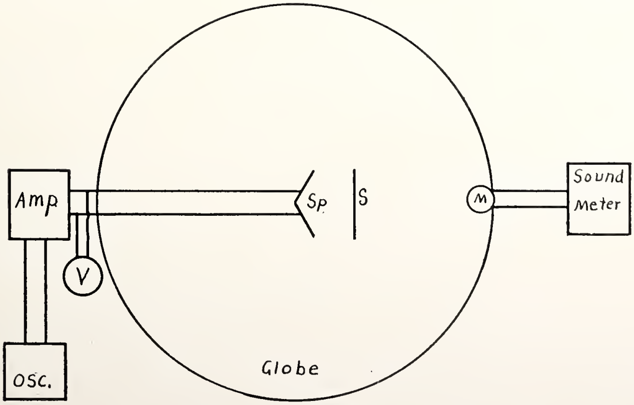

Fig. 2.

So a constant frequency variation moves the node at the lower frequency to a loop at the high frequency limit and back again. An ideal frequency wobbler would be a heterodyne, beat oscillator, for it can be shown that a constant variation in the condenser capacitance in the fixed frequency circuit will produce a constant variation in the output frequency regardless of the frequency at which the oscillator is set.

The experimental set up is shown in Figure 2. A Clough Brengle audio oscillator, variable from 50 to 16,000 cycles was used. The frequency was wobbled 460 cycles on each side of the set value by paralleling the condenser in the fixed frequency circuit of the oscillator with a small variable air condenser and rotating its rotor at 500 revolutions per minute by a small motor. Each frequency was set with the plates of the rotable condenser half meshed so that the capacitance, and hence the frequency, was varied equally above and below the set frequency.

The oscillator was connected through an amplifier to a Wright De Coster speaker placed in a globe photometer three feet in diameter. The microphone of a General Radio Sound Level meter was placed in the window of the globe. A shield was placed between the speaker and microphone to protect the microphone from direct radiation from the speaker.

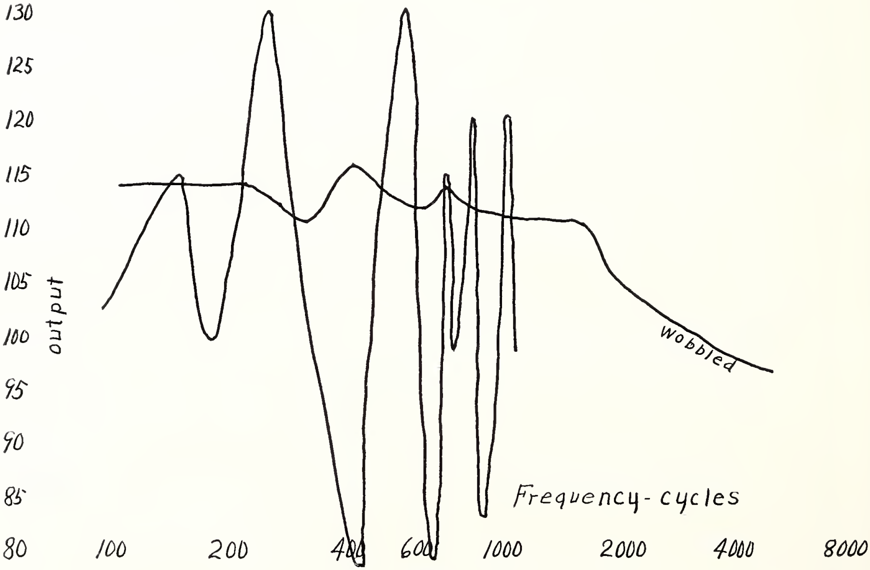

Fig. 3.

Figure 3 shows runs made with and without wobbling the frequency and is convincing proof that the sound intensity is not constant in an enclosure. The peaks occur at a fairly constant frequency increment and are, hence, due to standing waves in the globe. Due to the logarithmic scale of frequencies, the separate peaks cannot be shown beyond 1000 cycles. Hence the curve in this region is the individual readings at each even 100 or 1000 cycles.

Next the frequency was wobbled above and below the set frequency and the curve superposed on the first curve in Figure 3 to show the smoothing effect.

Figure 4 shows the frequency characteristic of the same speaker taken out of doors. The speaker was mounted on a turntable arranged to be turned on two axes at right angles to each other, and the microphone was left at a fixed position. Twenty-one frequencies were used from 50 to 8000 cycles and twenty-one different angles of the speaker. The averages of these readings were taken as proportional to the total output of the speaker at any particular frequency. The readings were not reduced to an absolute level, as relative values only were needed. All output readings are the decibel readings of the sound level meter. The open air and globe-wobbled frequency curves are superposed to show the correlation between the two.

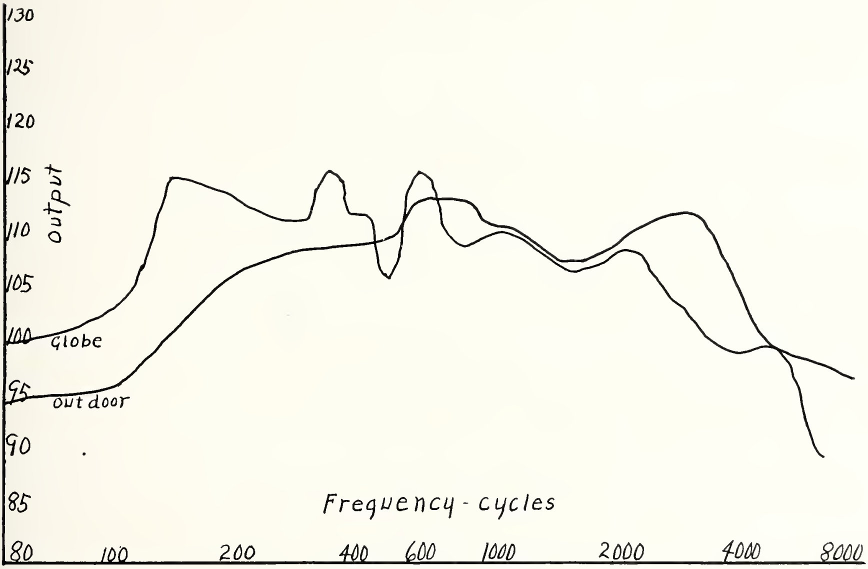

Fig. 4.

It is felt that the globe method of measuring the total output of speakers offers a considerable advantage over the rather cumbersome methods used heretofore.

This experiment was conducted in the physics laboratory of Indiana University and the electrical engineering laboratory of Ohio University under the direction of Professor R. R. Ramsey of the Indiana department of Physics.

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SECTION ON PSYCHOLOGY

Chairman: A. R. Eikenberry, Manchester College

Attendance at the meetings of the Section on Psychology was reported to be the largest of any meeting to date, approximately 150 persons attending some of the meetings.

At the luncheon meeting Dr. George A. Kelly, of Fort Hays Kansas State College, presented an interesting discussion on the place of the psychologist in the small school system.

Dr. F. B. Knight, of Purdue University, was chosen chairman of the section for 1939. The following were named to constitute the program committee: Fowler D. Brooks, DePauw University; Irvin T. Shultz, Butler University; and R. C. Davis, Indiana University.

ABSTRACTS

Orientations in mental deficiency. L. P. Harshman, Fort Wayne State School.—The approach to the problem of feeblemindedness is more than a study of distribution, classification, limited education, and some form of institutional care. There must be a study in the mental dynamics of the patient as applied to his individual problems of challenging the world. Stresses should be made on the reciprocal relations of importance in determining the social destinies of the defective. Only by such an approach can there grow a consciousness and a common concern relative to mental hygiene's biggest problem.

The place of the psychologist in the small school system. Geo. A. Kelly, Fort Hays Kansas State College.—Attempts to increase the annual production of the school plant have resulted in a type of organization in which administrators are removed from pupils and teachers and compelled to recognize greater responsibilities to administrative regulations and to curricula and less responsibility for the welfare of individual pupils. If the school psychologist is simply to be another specialist, we cannot justify his existence in a small school system. The place of the psychologist should be envisaged as that of a teacher without curriculum, whose major responsibility is to assist individual pupils and teachers. An outline of the typical activities of such a psychologist in a small system is presented, together with suggested plans for including his salary in the budget.

Persistence of attitudes concerning conservation issues. A. C. Williamson and H. H. Remmers, Purdue University.—The problem of this study was two-fold: first, to measure persistence of group attitudes changed by means of defined social stimulus material, and second, to measure the variability of the groups to discover whether they become more or less homogeneous after the presentation of such material. The results indicate that there is a significant change in attitude and in variability, and this change persists over a period of time—in this study, four months for the urban group and eight months for the rural group.

An experimental comparison of old and young coördinations in normal college adults and diagnosed pathological cases. BRYAN PAYNE, Indiana University.—With the use of the mirror-vision technique, we have been able to measure, on the one hand, the efficiency of a coördination that is genetically old in the life of the subject and, on the other hand, the efficiency of another coördination beginning relatively not so far from zero. In this study we have measured the efficiency of a day's practice in mirror-vision and of a day's practice in direct-vision for 78 diagnosed pathological cases. A day's practice consisted of ten repetitions of the task, each repetition being separated by an interval of one-half minute. Comparisons have been made with the efficiencies of normal college adults practicing under identical conditions. The following summary and conclusions seem warranted by the results of this study: (1) Pathological cases are reliably lower in direct-vision efficiency than normal college adults. (2) Pathological cases are reliably lower in mirror-vision efficiency than normal college adults. (3) The difference between direct-vision and mirror-vision efficiencies is relatively greater for pathological cases than for normal college adults. The greater deviation lies in the direction of the mirror-vision efficiency, i. e., the pathological cases are relatively lower in mirror-vision efficiency than in direct-vision efficiency. (4) We interpret these facts to mean that, while the old habit patterns are somewhat disturbed in the pathological state, they are not disturbed to the extent that the more embryonic pattern is. In terms of the eye-hand coördination, abnormality is more largely in the direction of an inability to build up the new coördination than it is to maintain the old in the face of stimulation.

A simple and direct approach to measurement of the attention value of advertising copy through eye-movement photography. JAMES S. KARSLAKE and JOSEPH TIFFIN, Purdue University.—A photographic technique placing advertising copy at reading distance and approximating normal reading conditions has been developed to meet very nicely precisely those factors which are peculiar to the determination of consumer interest in advertising. A method of direct photography, recording eye-movements by reflection from a half-silvered mirror together with a picture of the page or pages by transmission through the mirror, has been found to yield to a sufficiently accurate approximation of fixation areas just what material, if any, is of consumer interest. Six people without previous experience were able to judge ten looks at several pages of a well-known periodical, correctly identifying 58 of their combined total of 60 placements.

The distribution of muscular action potentials during maze learning. ROBERT S. DANIEL, Indiana University.—The problem of the amount of muscular tension concomitant with the acquisition of a motor skill in an assigned task is the basis of this research. Results of the study indicate a differential level of tension for the four body positions studied, which is maintained throughout the learning. However, the most significant conclusions are derived from the curves of the progress of tensions as the task is mastered. Early tensions were high as the subject approached the job. Tension levels fall in every member towards the middle of the practice series, then rise again as the last trial approaches. Statistically, the early decline in tensions (progressive relaxation) is associated with the attempt of the subject to eliminate errors or to achieve accuracy. The later rise in tensions is in the same way associated with the attempt of the subject to increase his speed. This interpretation of the results is made in connection with a peripheral-motor theory of learning.

An experiment in shifting attitudes. HARRY MASON, Purdue University.—A group of 57 seniors in the West Lafayettte High School were given attitude scales concerning the attitude object: That a half-time schedule of opportunities to learn while on jobs in businesses be substituted for the traditional system of high school administration. A test of information on subjects relating to the vocational adjustments of youth was also presented. Propaganda intended to shift attitudes toward favor for the proposal was introduced, and the same scales and tests repeated. Interesting relationships between attitudes, intelligence, and information were evident upon analysis of the data by statistical means. By use of two techniques of measurement of attitude, some theoretical considerations of measurement in this field were brought to light.

A practical test for punch press operators. NATHAN B. GEWIRTZ, Purdue University.—Following the principle that a psychological aptitude test is usually more valid when it closely approximates the job, a test for punch press operators has been constructed, the press of the same general design as that used in industry. The operator is asked to put 50 plates through the press four times, making a total of 200 pieces. Two scores are obtained—a time score and an error score. Preliminary norms, as well as a comparison between unselected persons and experienced punch press operators, are presented. Correlations obtained from this preliminary data between efficiency ratings and scores on the test are discussed.

Industrial psychology. JOSEPH TIFFIN, Purdue University.—The test, used to supplement present methods of employment, attempt to give a picture of the actual efficiency of an employee before he is hired. In each case the test is "tested" on present operators before it is recommended to the employment manager. "Testing" the test on present operators involves giving the test to a fairly large number of present employees and determining whether those who test high tend in general to be more efficient than those who test low. In this way it may be determined definitely whether the test will pick efficient operators. Obviously, in using present employees to test the test, the results would have no bearing whatsoever upon the present status of those employees of the company. An experimental testing program of the type described has been under way for some time in two plants. Results show clearly that manipulative operators can be selected with considerable precision by means of such tests as finger dexterity, hand precision, and keenness of vision.

The person as a laboratory subject, as a statistical case, and as a clinical client. GEO. A. KELLY, Fort Hays Kansas State College.—The definition of the science of psychology eventually will be written by those who are not psychologists. It is difficult for anyone except a confirmed psychologist to see the laboratory subjects of the academic psychologists as the same human beings who inhabit the land. It is somewhat easier for an administrator, an economist, or a social worker to recognize the statistician's case as a workable entity. Great numbers of intelligent and interested laymen who have been newly awakened to so-called human values are thinking in terms of clinical clients and what the psychologist does for them. This forcing of the psychologist's hand may draw him into scientific inaccuracies or may cast for him a new and more vital role. Illustrations of the problems which psychologists will be expected to solve are offered.

Responses of Psychotic Patients to the Thurstone Personality Schedule before and after Metrazol Treatment

Willis H. McCann, Indiana University

This research[1] took place at the Missouri State Hospital for the Insane at Nevada, Missouri, during the summer of 1938. The purpose of the investigation was to see how psychotic patients would respond to the Thurstone personality schedule before and after receiving the metrazol shock treatment.

Because of the short period of time available, the investigation was limited to 26 patients, 12 males and 14 females, ranging from 17 to 52 years of age. According to the hospital classifications, 21 were schizophrenes (12 hebephrenics, 4 paranoids, 3 simplex, and 2 catatonic); 4 were manic-depressives (2 depressed and 2 maniacal); and one was a case of involutional melancholia. All 26 had been admitted to the hospital since 1930, and half of them had been admitted in 1938.

Before beginning the metrazol treatments 11 of these patients gave "yes", "no", or "doubtful" responses to the questionnaire. The remaining 15 patients were either unwilling or unable to cooperate. Metrazol was given on an average of twice a week for an indefinite period, depending upon the progress of the patient. The initial amount of 2.5 cc. for females and 5 cc. for males was increased from time to time so that each successive injection would produce the so-called "shock" or "convulsion."

The answers to the questionnaire were scored according to the Thurstone scoring system and also according to the method devised by Dr. E. S. Conklin of Indiana University.[2] With Dr. Conklin's scoring device an abnormal, a psychotic, and a schizoid score were obtained for each personality schedule.

There were only five patients who cooperated by giving "yes", "no", or "doubtful" answers both before and after receiving metrazol. Their Thurstone scores ranged from 39 to 117 with an average score of 81.6 before metrazol and from 42 to 153 with an average score of 82.4 after metrazol. Their abnormal scores (which, for 100 college students, averaged 7.45) ranged from 11 to 26 with an average score of 22.4 before metrazol and from 9 to 38 with an average score of 19.2 after metrazol. Their psychotic scores (which, for 100 college students, averaged 5.18) ranged from 6 to 13 with an average score of 8.6 before metrazol and from 1 to 15 with an average score of 7.4 after metrazol. Their schizoid scores (which, for 100 college students, averaged 3.93) ranged from 3 to 11 with an average score of 6.6 before metrazol and from 1 to 17 with an average score of 7.8 after metrazol. The number of metrazol treatments ranged from 6 to 13 with an average of 10.4. Of these five patients, one, a hebephrene, showed definite improvement; two, a hebephrene and a simple type, remained unchanged; and two, a hebephrene and a paranoid type, became definitely worse. These observations were corroborated by the hospital staff, with one exception, a 22 year old girl classified as schizophrenia, simple type, who showed some improvement although her scores indicated no change in her condition.

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[1] This research was suggested by Dr. E. S. Conklin, Indiana University.

[2] Conklin, E. S., 1937. Three diagnostic scorings for the Thurstone personality schedule. Indiana Univ. Publ., Sci. Ser. 6.

Six patients gave "yes", "no", or "doubtful" answers before receiving metrazol but were unwilling or unable to cooperate after receiving the treatment. Their Thurstone scores ranged from 36 to 131 with an average score of 88; their abnormal scores ranged from 9 to 33 with an average score of 23.8; their psychotic scores ranged from 3 to 13 with an average score of 9.5; and their schizoid scores ranged from 3 to 13 with an average score of 10. The number of metrazol treatments ranged from 10 to 19 with an average of 13.1. All six (two hebephrenes, one paranoid type, one simple type, one depressed, and one maniacal) became worse during the series of treatments. One of them, a 34-year-old male classified as schizophrenia, paranoid type, had been admitted to the hospital in 1934 and since then had received a series of 53 insulin treatments. He also had received a series of 10 metrazol treatments during the spring of 1938. During the present metrazol series his condition became much worse. These observations were all corroborated by the hospital staff.

Twelve patients were unwilling or unable to cooperate before receiving metrazol but gave "yes", "no", or "doubtful" responses to the questionnaire after the treatment. Their Thurstone scores, which it must be remembered were obtained only after metrazol treatments, ranged from 13 to 106 with an average of 50.4. Their abnormal scores ranged from 5 to 26 with an average of 12.0. Their psychotic scores ranged from 1 to 13 with an average of 7.0, and their schizoid scores ranged from 2 to 10 with an average of 5.3. The number of metrazol treatments ranged from 5 to 21 with an average of 11.5. All twelve of these patients (five hebephrenes, two paranoids, two catatonics, one depressed, one maniacal, and one involutional melancholia) showed improvement, and six of them were paroled from the hospital.

Three patients were unwilling or unable to cooperate both before and after receiving metrazol. One of them was a 24-year-old male, classified as schizophrenia, simple type. He was admitted to the hospital in 1934 and since that time had received a series of 59 insulin treatments. In the spring of 1938 he received a series of 24 metrazol treatments, and during the present metrazol series he received 7 treatments. His condition was apparently becoming much worse. Another was a 25-year-old female, classified as schizophrenia, hebephrenic type. She was admitted to the hospital in 1930 and had not received any insulin or metrazol prior to the present series of treatments. After receiving 11 metrazol treatments her condition was also becoming much worse. The third patient was a 25-year-old male classified as schizophrenia, hebephrenic type. He was admitted to the hospital in 1937 and later paroled after receiving a series of 25 insulin treatments. This patient was returned to the hospital last July and immediately started the metrazol series. No change was apparent in his condition after seven treatments.

These results may be summarized as follows: Of 26 patients, five gave "yes," "no," or "doubtful" responses to the questionnaire both before and after receiving metrazol. Only one of these five showed definite improvement, two remained approximately unchanged, and two became definitely worse. Six patients gave "yes," "no," or "doubtful" answers before receiving metrazol but were unwilling or unable to cooperate after the treatments. Twelve were unwilling or unable to cooperate before receiving metrazol but did cooperate after the series of treatments. Three were unwilling or unable to cooperate both before and after the series of treatments. Judged by their reactions to the questionnaire, 13 of the 26 showed improvement, five remained approximately unchanged, and eight became definitely worse. These data are, of course, suggestive rather than conclusive. In general, they indicate that either the metrazol produced no consistent pattern of change in the personalities of the 26 patients or our method of measuring personality changes was inadequate.

Measuring Affective Experience

H. E. Geiger, Purdue University

The Problem

The experiment which I am reporting was designed to investigate a problem directed toward further simplification and improvement of attitude measurement techniques. Since the study is still under way, it will be possible to give in this paper only a brief resume of a preliminary study and a description of the progress and the objectives of the major study. The nucleus of this investigation has grown out of a rather critical analysis of the several methods which have been used in the measurement of attitudes.

It may be recalled that most of the instruments used in measuring attitudes make use of statements about some attitude object. In some of the scales, such as those begun by Thurstone[1] and the variations developed by Remmers,[2] subjects are allowed to express their attitudes by indicating those statements with which they agree. In others, such as those proposed by Likert,[3] subjects are allowed to indicate an amount or degree of agreement with statements.

When these statements are carefully analyzed, it may be observed that usually only one or two words in each statement are important in determining its favorableness or unfavorableness. A few words, such as "interesting" and "uninteresting" or "desirable" and "undesirable," are the key words which allow subjects to express favorable and unfavorable responses. Some statements have contained qualifying words expressing how desirable or how interesting, as for example "slightly interesting" or "very desirable."

This paper is primarily concerned with the functioning of these key words. They may be classified into two types, those indicating favorableness or unfavorableness which we shall call "directional words" and those indicating an amount of favorableness or unfavorableness which we shall call "intensity words."

If the element in the language which indicates an individual's attitude is contained in these directional words and intensity words, it would seem to be possible to combine them into phrases, obtain scale values for these phrases, and use them in much the same way that statements have previously been used in attitude measurement. For example, the directional word "inspiring" which points toward or indicates a favorable reaction, plus the intensity word "greatly" which tells how inspiring, together constitute the phrase "greatly inspiring" which, it would seem, could be used to express how one felt about a speech, a teacher, or a book. If scale values could be obtained for all such phrases expressing the direction and the intensity of one's reactions, it should be possible to measure reaction toward any situation by simply selecting appropriate phrases from the list.

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[1] Thurstone, L. L., and Chave, E. J., 1929. Measurement of attitude toward the church. Univ. Chicago Press. p. 2.

[2] Remmers, H. H., 1934. Studies in attitudes. Studies in Higher Educ., 26; Bull. Purdue Univ. 35.

[3] Likert, Rensis, 1932-33. A technique for the measurement of attitudes. Archiv. Psychol. 22.

In terms of attitudes if one wished to measure, let us say, attitude toward a teacher, he would need to select from the list of scaled phrases a number of phrases which would allow one to express a reaction toward a teacher. That group of phrases might then be thought of as a scaled measuring instrument since values for each of the phrases would be known. In a similar manner other groups of phrases might be selected for measuring other attitudes. Such a technique would greatly reduce the labor involved in the construction of measuring instruments and, at the same time, increase the possibility of measurement to an infinite number of objects or situations.

Preliminary Experiment

At the time this problem was being formulated it became possible, in connection with another study, to test out, in a measure, the success which might be expected in scaling phrases apart from other sentence structure. Although the phrases in this preliminary study required a comparison of two objects or situations, the study seemed to support the hypothesis that single phrases may be scaled quite successfully.

In this preliminary experiment, 14 phrases expressing degrees of comparison were used. They were designed to represent two continuums as follows: (1) Very much inferior, much inferior, slightly inferior, equally as good, slightly superior, much superior, very much superior; (2) very much less often, much less often, slightly less often, equally as often, slightly more often, much more often, very much more often.

Scale values were obtained separately for each of these expressions by the psychophysical method of equally often observed differences. The sheet which you have indicates graphically the scale values for the two continuums. The tables show the scale and Q-values on a 7-point continuum and the probable Q-values on an 11-point continuum. It will be noted that the expressions received values on a 7-point continuum which closely correspond to the seven integers spaced at equal intervals along an arbitrary continuum. Q-values compare very favorably with Q-values obtained on items which have been used in attitude scales. From the results obtained in this preliminary experiment the scaling of single phrases seemed plausible, and the major experiment was set up.

The first step in the major experiment was the selection of a sufficiently extensive list of suitable phrases. A preliminary investigation of words and their meanings seemed to indicate that such phrases might well be limited to those expressing an affective experience. They are, at least from the standpoint of logic, the fundamental expressions of attitude; and, inasmuch as it may be observed that many statements used in attitude scales simply describe the attitude object, it would seem possible that such statements might be less indicative of a true reaction than statements directly expressing affective experience. Attitude can only be secondarily inferred from a descriptive statement. For example, if a child said that a teacher was strict, we should probably infer that the child disliked the teacher, but quite the contrary may have been true. On the other hand, if the child said that he liked or disliked the teacher's rules, there could be no mistake. Of course, this is a hypothesis, and its empirical validation should be considered as an auxiliary part of this experiment.

With this delimitation to words clearly expressing an affective experience, Roget's *Thesaurus of English Words and Phrases* was carefully searched for all suitable words, and the three following lists were compiled.

1. Directional words expressing a favorable response.
2. Directional words expressing an unfavorable response.
3. A list of intensity words which could be used to express an amount or degree of favorableness or unfavorableness.

Words having equivocal meaning were eliminated. Even though such words as "thrill" and "provoke" express affective experience, they are not useful as directional words because they sometimes have favorable and sometimes unfavorable connotations.

After the undesirable words were eliminated, there remained 108 positive directional words, such as acceptable and admirable, 146 negative directional words, such as disagreeable and displeasing, and eight intensity words, such as slightly and decidedly. It is interesting to note that there are many more ways of expressing unfavorableness than there are of expressing favorableness.

The directional words were set up in tabular form in order to study their applicableness to many different types of objects and situations, and it was discovered that a rather small number of these words could be readily applied to most situations. Although it is planned eventually, if necessary, to obtain ratings on all of the directional words, each in combination with several different intensity words, for the present experiment only ten were taken from each of the favorable and unfavorable lists. It is believed that the number of intensity words it will be necessary to use may be reduced to as few as three or four when it is learned how advantageously they space themselves along the continuum.

The experiment has been carried only to the point of scaling. However, an exhaustive study of reliabilities and of various functions of measuring instruments made up of phrases selected from the scaled list has been outlined. If it is found that the scaled phrases function satisfactorily as measuring instruments, when the complete list is scaled it will be possible to measure any affective experience by simply using the appropriate phrases.

This experiment should be particularly interesting to those who have been interested in the science of semantics.

A Technique for Measuring Consumer Attitude Toward Any Advertisement

RUTH H. KARSLAKE, Purdue University

Most of the existing methods for evaluating advertising are unsatisfactory for various reasons. So-called laboratory techniques, which can most satisfactorily isolate the necessary variables, are often unsuitable because they create artificial situations which are not strictly comparable to the ones in which advertising is used. Those field surveys or measures of consumer response to advertising which give satisfactory results are impractical from the point of view of the costs involved. Also, the question of reliability of these methods has not been satisfactorily dealt with in many cases. It appears that there is needed a simple, economical instrument which may be used as a reliable index of the value of any advertisement as measured in terms of consumer reaction to it.

According to Link (3), "Among all methods of measuring the relative effectiveness of advertising, that of submitting ads to the judgment of selected groups of people would be the most valuable if its reliability could be determined."

In constructing such an instrument, it was decided to employ a technique suggested by Likert (2). For the measurement of attitudes he has evolved a method which he found to give as high reliabilities as were obtained by the Thurstone attitude scales (5). Likert's method, besides eliminating much of the labor involved in constructing a Thurstone scale, does not depend upon the principle of determining scale values for statements by means of a judging group. Recent studies at Purdue (1) have demonstrated that this method can be satisfactorily applied to the type of statements used in the generalized attitude scales developed by Remmers (4).

Accordingly, it became the purpose of the present study to construct and evaluate an instrument, following Likert's technique, for the measurement of consumer attitude toward any advertisement.

Likert's method involves a battery of statements expressing various attitudes toward an attitude object. Each statement is a scale in itself by virtue of the several alternatives by which the subject responds to it. The present study employed the following seven alternatives of response to each statement: strongly agree, agree, mildly agree, indifferent, mildly disagree, disagree, strongly disagree. Following Likert, the investigator found a satisfactory method of scoring to be the assigning of numerical values from 7 to 1 to each of these response alternatives. In statements expressing a negative attitude, this weighting was reversed. An individual's score could then be computed by averaging or summing the numerical value of the response to each statement, a comparatively high score expressing a more favorable attitude than one which is comparatively low.

The first step in the construction of the instrument was the collection of statements which would be indicative of consumer attitude toward any advertisement. In order to make these as representative as possible, the reactions of 25 subjects to 30 advertisements were collected. These were full-page advertisements, both colored and uncolored, which seemed representative of good and poor advertising for certain products for which the group might be expected to be potential consumers.

From these reactions, 354 statements which seemed most suitable were assembled. The second step, was the judging of the statements by six members of the psychology staff of Purdue University. They rated the statements as good, fair, and poor, in accordance with a criteria set up for them as to the purpose of the instrument.

The third step was the selection for a preliminary battery of the 50 statements indicated by the judges' ratings to be the best. Each statement chosen was rated good by at least five of the six judges. Twenty-five positive and 25 negative statements were chosen by the investigator from the group which seemed best according to the judgments expressed.

The fourth step involved the administration of the preliminary instrument to 50 subjects, 25 men and 25 women, associated with Purdue University. Each subject rated each of six advertisements on the basis of these 50 statements. Six full-page advertisements, five colored and one uncolored, were used. Three displayed products; two, services; and one, good-will.

From scores obtained by summing the numerical values of the subject's response to each statement, the instrument was evaluated as to reliability and validity. Reliabilities of the instrument for the first four advertisements were found by the split-half method of correlation. These ranged from .96±.01 to .98±.003. In view of these very high reliabilities and the fact that the instrument seemed too long to be practical, the Spearman Brown formula was applied to determine what the reliability would become if the test were shortened to 40% of its present length. R's were predicted of .90±.02 to .95±.01, indicating satisfactory reliability if the instrument followed the prediction.

By computing the percentages of subjects whose total score on the battery for a given advertisement was at or above the indifference point, a rank order rating of the advertisements was obtained for the scale data. A validating criterion, based upon reactions of another group to these same advertisements, also enabled a rank order of preference to be established. For the two techniques the ranks were identical except for the reversed order ranking of the advertisements standing 1 and 2 and 4 and 5. A rank difference correlation was found to yield a P of .93±.01.

The number of statements was reduced to 20 for the final instrument by selecting those which seemed to be the most discriminating of a favorable or an unfavorable attitude, on the basis of the number of responses of indifferent which each received for all of the six advertisements. Ten positive and ten negative statements were selected.

The data from the preliminary administration were rescored on the basis of the 20 statements selected for the final scale. The split-half reliabilities ranged from .89±.02 to .94±.01. Since these all fell within the allowable error range of the reliabilities for 20 statements predicted by the formula, it seems that the Spearman-Brown formula did predict accurately for this data.

A second group of 25 men and 25 women students of Purdue University were then asked to rate the same advertisements on the basis of the final instrument of 20 statements. Split-half reliabilities were found to range from .78±.04 to .94±.01.

In order to have a larger group upon which to base the reliabilities, it was considered desirable to combine the data obtained from the first group on the basis of 20 statements with that of the second group. That the groups were fairly comparable was shown by the similarity of the sigmas of the distributions of their scores. Split-half reliabilities for the entire group of 100 were found to range from .84±.02 to .92±.01. Ranking by percentages gave the same order of preference as was obtained from the 50 subjects on 50 statements. Therefore, the rank difference correlation with the criterion was again found to be .94±.01.

It would seem that within limitations imposed by method the instrument appears to give satisfactory results. Although the numbers of subjects used were too small to be conclusive, it appears that the instrument is measuring, by the crude index employed, a function rather closely related to that of the validating criterion. So far as the conditions of this investigation permit, the battery appears to be reasonably satisfactory. It should be useful, especially in view of its simplicity and economy, as a means of determining the relative merits of various types of advertising.

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The Construction and Evaluation of a Scale to Measure Attitudes of Stutterers Toward Any Social Situation

ELNA S. HUFFMAN, Purdue University

Introduction

During the past decade the psychology of stuttering has become a matter of growing interest and concern. Attitudes of stutterers have been determined by case histories, biographies, questionnaires, and rating scales. It is desirable to replace these crude methods with more rigorous and exact methods of measurement. The primary purpose of this study was to construct an attitude scale to measure attitudes toward any social situation.

The Thurstone technique of attitude scaling, based on the assumption that equally often observed differences are equal, was used throughout the study.[1] By applying the Remmers' modifications,[2] a master scale was constructed which can measure attitude toward several social situations at the same time. The acceptance or rejection of statements of opinion was used as the index to affect measurement.

Scale I construction:—A number of statements of opinion, general in nature and applicable to both stutterers and non-stutterers, was collected and submitted to five members of the psychology staff at Purdue for rating on a 3-point scale: (1) excellent, (2) fair, (3) worthless. All statements checked worthless by two or more judges were eliminated. Remaining statements were mimeographed and administered to 223 college students for allocation on an 11-point scale, according to the degree of favorableness[3] or unfavorableness to any social situation indicated by the statement. Frequency distributions were then set up for each of the statements, and their respective medians and Q-values computed. The median value of a distribution for a statement became the scale-value for that particular statement. All statements having a Q-value of over three were discarded as being ambiguous. In assembling the scale, statements were selected so as to cover the whole range of favorableness and so as to be approximately equi-distant. Alternate forms were constructed by using as parallel statements those having approximately the same median and Q-values. The reliabilities of the scale-values were:

Form A, Standard Error of the Scale Value .108 ± .07 scale units
Form B, Standard Error of the Scale Value .109 ± .07 scale units

Scale I evaluation.—To determine reliability of the instrument, it was given to 200 college students. The correlation of Form A with Form B was .79±.02.

Validity was found by administering the scale to 2 groups judged to differ in attitude toward a social situation. Judges were the Assistant

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[1] Thurstone, L. L., and Chave, E. J., 1929. The measurement of attitude. Univ. Chicago Press.

[2] Remmers, H. H., and Silance, Ella B., 1934. A generalized attitude scale technique. Journ. Social Psychol. 5:298-312.

[3] Seashore, R. H., and Hevner, Kate, 1932. A time-saving device for construction of attitude scales. Journ. Social Psychol. 3:367-373.

Dean of Women, the Director of the Women's Residence Halls, and two sponsors in the Men's Residence Halls. There were 75 subjects in each group. The reliability of the difference between the means of the two groups yielded 97 chances in 100 of a true difference; using difference as determined by percentages, the chances were 100 in 100 of a significant difference.

Scale II construction.—Scale II, constructed specifically for stutterers, contained some items relating directly or indirectly to stuttering. Therefore, the statements were criticized by members of the Purdue Speech Clinic Staff and after revision sent to various speech clinics for stutterers to allocate on the 11-point scale of favorableness. Because of the extreme difficulty in obtaining subjects, there were only 76 raters. These statements were submitted to the same statistical procedure as Scale I. It is significant that, when the objective measure of ambiguity was applied, the majority of statements relating to stuttering proved to be ambiguous. The reliability of the scale-values were:

Form A, Standard Error of the Scale Value .213 ± .15 scale units
Form B, Standard Error of the Scale Value .211 ± .14 scale units

Reliability and Alternatives of Response.—The Problem: Does increasing 2½ times the alternatives for response to each statement of opinion increase the reliability of an attitude scale as predicted by the Spearman-Brown prophecy formula?

Two scales were constructed, identical in every respect except the possibilities of response. Each scale had equivalent forms. In the first scale, Forms A and B, the directions were to either agree or disagree with each statement of opinion. The other scale, Forms X and Y, offered the subject a choice of 7 responses to each statement: (1) Strongly agree; (2) Agree; (3) Mildly agree; (4) Indifferent; (5) Mildly disagree; (6) Disagree; (7) Strongly disagree. All four forms were given to 50 students.

The reliability of the test having but two alternatives of response was found to have approximately the same reliability as the scale having seven alternatives for response.

Correlation of Form A with Form B = .732 ± .04
Correlation of Form X with Form Y = .734 ± .04

Therefore, the tentative conclusion is that the reliability of an attitude scale is not increased by the addition of alternatives for response.

Conclusions

1. Scale I, the general scale applicable to both stutterers and non-stutterers, would be efficient as a means of measuring group attitudes toward any number of social situations.

2. Scale II, constructed specifically for stutterers, does not differ appreciably from Scale I, since most of the statements relating to stuttering had to be discarded.

3. Increasing alternatives for response to statements in an attitude scale does not increase the reliability of the scale as predicted by the Spearman-Brown prophecy formula. Conclusions, based on a population of less than 100, must be considered tentative. It is for further research to determine the accuracy of the indications of this experiment.

A Study of Sex Differences in Food Likes and Dislikes[1]

Lyle Tussing, Purdue University

Very little information is available concerning the food preferences of men and women. The kind of satisfaction people get out of eating shows a marked difference among individuals. Most people have favorite dishes and pet abominations among foods. Doubtless, violent dislikes for generally accepted foods frequently originate in unpleasant experiences connected with them. Such an experience might be indigestion. The reasons for extreme likes would be less easy to trace. They may have a similar origin in forgotten pleasures somehow connected with things that now arouse them.

Although there is a wide variation of preferences, it is recognized that in the last analysis all tastes in food can be reduced to four or at the most six fundamental kinds—sweet, sour, bitter, salt, alkaline, and metallic, separately and in combinations. Any blend of these with pressure, pain, warmth, cold, and various odors, make up all of the varieties of taste we experience in foods.

Not only are there individual likes and dislikes for foods, but also there is a belief in the existence of a definite sex difference in these likes and dislikes. Dunlap[2] makes the following statement:

> A recent investigation on the likes and dislikes of men and women has brought out the indication that woman is relatively stronger in her dislikings, man in his likings. There are matters of secondary desires and aversions, of course, and it is not certain yet that it is generally true. Yet, certain common-place observations, especially in regard to foods, seem to bear out this conclusion. The results of wider experimental work on this point will be important.

Procedure

In order to make a trustworthy investigation of the variations due to sex alone, it is essential to secure subjects for the investigation of both sexes who are near the same age, who have the same social status, and who have been subjected to like training and social surroundings. The complete fulfillment of these conditions, even in the most democratic community, is impossible. Probably the nearest approach among adults to the ideal requirement is afforded by the undergraduate students of a co-educational institution.

The individuals who furnished the basis for the present study were students of Beloit College, Beloit, Wisconsin. They were from all four classes, freshman, sophomore, junior, and senior. Their ages ranged from 17 to 25 years. Questionnaires were given to these young men and women with the following instructions:

> Below are lists of foods which we would like to have you check (√) according to whether you *like* them, are *indifferent* to them, *dislike* them, or have *never tasted* them. p. 228.

Four columns were provided for checking and headed with the above titles.

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[1] The data reported here were gathered at Beloit College. F. Dunlap and B. Woodruff kindly assisted in the collection and tabulation of the questionnaire reports.

[2] Dunlap, Knight. Social psychology. Williams and Wilkins. p. 42.

Only the columns of "like" and "dislike" were tabulated, but it was considered necessary to include the other two columns in the questionnaire form so that the subjects would not be inclined to check as "dislike" all foods which were not actively liked and as "like" all foods not actively disliked. In other words, we were interested to know whether their reaction was one of approaching or avoiding. This procedure also explains why the percentages of the "like" and "dislike" columns do not total 100% in each case. A certain percentage of items were eliminated from the record sheet because they were checked as either "never tasted" or "indifferent." Questionnaires were returned from 184 males and 214 females.

The list of 289 items of food was assembled by consulting numerous cook books and manuals on home economics. Not all of the possible foods were listed nor all of the ways of preparing them. The list, however, was considered as presenting a fairly representative selection of foods and could be used effectively in the time available.

Results

The percentage of men and women liking and disliking was figured by dividing the number checking the liked (or disliked) column by the total number of that sex and computing it to the nearest whole number. However, fractions less than 1 (0 to 1) were considered 1%. To a large extent edibles which are liked by a large majority of men are also liked by a large majority of women. Some items which show a wide variation between the sexes include raisin and mincemeat pie, milk, poached eggs, rice, coconut cake, tuna fish, grouse, quail, and figs. There is also a similarity between the sexes regarding their dislikes. Here, such foods as raisin pie, avacados, milk, rice pudding, and creamed cabbage show the greatest differences.

When we consider the foodstuffs which are liked, we find that 172 of the 289 items are liked by a greater percentage of men than women, 23 are liked to the same extent, and 94 items are liked more by the women than by the men. Or from the percentage standpoint, 59% of all the foods liked are liked to a greater extent by men than by women, 8% show the same liking by the sexes, and 33% show a greater liking by the women. When we examine the food disliked, we find that the women indicate a greater dislike than the men for 174 items (60%); in 80 items (28%) the difference is in favor of the men, and in 35 items (12%) they are the same. From this it appears that the ratio is about 2 to 1 in both the likes and dislikes, a greater percentage of women disliking items and a greater percentage of men liking them.

There is a statistically significant difference[3] in 49 cases. Of the 172 items liked by men we find that 31 items show a significant difference. Of the 94 foods liked more by the women than by the men, 4 were significant. In the dislikes there are three cases having a significant difference in favor of the men and 11 in favor of the women.

From this investigation of food preferences it appears that women are relatively stronger in their dislikes; men, in their likes.

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[3] Garrett, H. E., 1937. Statistics in psychology and education. Longmans, Green. p. 228.

SECTION ON ZOOLOGY

Chairman: HENRY G. NESTER, Butler University

The attendance at the section on zoology maintained an average of between 50 and 60 throughout the session. The following named demonstrations were given: the use of the Argus camera in the biological laboratory, Caudata of Vigo County, juvenile forms of Acanthocephala, and the spotted turtle, *Clemmys guttata.* Other papers were also supplemented by demonstration material.

C. P. Hickman, of De Pauw University, was elected chairman of the section for 1939.

ABSTRACTS

The centennial of the cell theory of Schleiden and Schwann, 1838-1938. HENRY G. NESTER, Butler University.—Biographical sketches of the two authors of the cell theory are given. Some of Schwann's scientific work is mentioned. Schwann's "Microscopical Researches into the Accordance in the Structure and Growth of Animals and Plants" and Schleiden's "Contributions to Phytogenesis" are reviewed. Bibliographies of the two men are included.

Insects of Indiana for 1938. J. J. DAVIS, Purdue University.—Each year finds us confronted with a changed insect population. During the past year many insect problems have confronted the citizens of Indiana. Army worms destroyed field crops early in the season; grasshoppers were abundant, but, because of the heavy rainfall and resulting luxuriant vegetation, they did not cause severe losses; the Hessian fly built up to threatening numbers, especially in the northern half of the state; and for the first time since its introduction into Indiana, the European corn borer caused commercial losses in the eastern part of the state. Garden pests, especially the Mexican bean beetle and leafhoppers, caused severe losses in many parts of Indiana. Annoying pests, including mosquitoes and fleas were unusually abundant. Scale insects, including the European elm scale, the cottony maple scale, and the San Jose scale, were on the increase. Fruits were likewise subject to heavy toll by the Oriental fruit worm and codling moth. These and many others are discussed.

Further observations on conditions under which fresh-water medusa, *Craspedacusta*, occurs. MURVEL R. GARNER, Earlham College.—The medusa has now been found to occur in seven of the last eight years in this same body of water, indicating that conditions appear to be satisfactory for its permanent residence there. Furthermore, the medusae have been found in two other artificial bodies of water within a few miles of Richmond, one of which has contained them at least three or four summers. As a means of determining the conditions under which these animals live, physical and chemical data concerning the water and a description of the bodies of water are given. It is hoped that other investigators will contribute similar data as a means of determining the conditions of occurrence of this form.

Radiation of Drosophila with low-intensity ultra-violet light for one complete generation. III. Effect on crossing-over in the second chromo-

some of the male. S. A. RIFENBURGH and MARTHA WALKER, Purdue University.—Abstract withheld until study is complete.

The Golgi material in the parathyroid gland cells of vitamin-D-deficient albino rats. HENRY G. NESTER, Butler University.—Ten albino rats, the mothers of which had been on a diet deficient in vitamin D during lactation, were placed on Steenback ricket-producing diet 2965 when 29 days old and kept on it for 31 days. They were then killed and the parathyroids preserved in a modification of the Nassanov Kolatchev method, and the tibias were tested by the McCollum line test. The same procedure was followed with animals kept on a normal diet. Preliminary observations show that the Golgi apparatus of the parathyroid gland cells of animals receiving a normal diet is larger and more complex than that in the animals deficient in vitamin D.

A preliminary report on the life history of a species of Amphimerus (Trematoda: Opisthorchiidae) from the snapping turtle *(Chelydra serpentina)*. RAYMOND M. CABLE, Purdue University.—Among a large number of parasites found in a snapping turtle from Madison County, Kentucky, were 42 specimens of Amphimerus, which were taken from the gall bladder and bile ducts. Twenty-two of these were teased apart and placed in aerated water until the eggs contained active miracida, but none of the eggs were observed to hatch. Each of 10 small specimens of *Goniobasis semicarinata* was isolated with a small portion of worm material containing embryonated eggs, and at intervals the snails were cracked and examined for parasites. One died, four became infected, and five gave negative results. The last infected snail, examined 90 days after infection, contained 24 cercariae that were capable of swimming. The other infected specimens did not contain mature cercariae but yielded large numbers of rediae of the type characterizing the Pleurolophocera group. Both mother and daughter rediae were observed, apparently for the first time in this group. Larval stages of none of the other seven trematodes known to parasitize this snail were found in the experimental material. Since the natural incidence of infection with all species is low in this mollusk, and the specimens used were very small, it seems quite probable that the infection resulted from the ingestion of the eggs of the parasite. The second intermediate host has not been discovered.

Star-recessive and Trim, spontaneous mutations on the second chromosome of *Drosophila melanogaster*. EDWARD B. LEWIS, JR., Minneapolis, Minn.—Star-recessive (symbol S^r), a recessive allelomorph of the dominant gene for Star-eye (S, 2-1.3), produces a rough eye in the homozygous state. Its phenotypic expression, however, is more variable than that of S/+, while the combination S/ S^r results in a new phenotype. A series of experiments show S^r to be located on the second chromosome and prove its allelomorphism with Star. Trim (symbol trm) is a recessive mutation resulting in scalloped wing margins. An interesting feature is the complete infertility of the homozygous trm female—a condition uncommon although not unique among autosomal recessives. The final localization of trm is made by a special type of crossing-over experiment known as a balanced viability test.

Notes on the Hypogaeic Ant, *Proceratium silaceum* Roger

CLARENCE HAMILTON KENNEDY, Ohio State University, and MARY TALBOT,
Lindenwood College, St. Charles, Missouri

To complete the technical description of the species we give first a description of the male, which to date has remained undescribed.

Description of the Male

The following description deals largely with characters which differ from parallel characters in the male of *Proceratium croceum* Emery described by M. R. Smith (**1930**). The type male is from a nest of 5 males and 9 workers collected by C. A. Dennis on the south sand spit of Pelee Island, Ont., August 25, 1936 (Kennedy coll., No. 2361). The workers are of the lighter of the two forms of *silaceum* discussed elsewhere in this article. We have no males of the darker form. Neither have we been able to study males of *croceum*.

Length 3 mm. Length of face, excluding mandibles, into width, including compound eyes, 1 1-3 times ("slightly" broader than long in *croceum*).

Antenna, 12 segments, scape and first segment of funicle shiny; the other funicular segments dull. Scape equal in length to first 4 segments of funicle (equal to first 3 segments in Smith's fig. 3 of male *croceum*). Reticulation of face with 10-12 polygonal areas between compound eye and median ocellus (5 in Smith's fig. 3 of male *croceum*).

Mesonotum with very narrow median carina; scutellum with similar but a more distinct carina (in *croceum* not distinct enough on mesonotum for mention). Metanotum with median, posterior spine as in *croceum*. Epinotum with its posterior vertical face two times as long as dorsal surface (more nearly equal in *croceum*, Smith's fig. 2). Median furrow of epinotum wide and shallow, most distinct on upper half of vertical face (in *croceum* more distinct on the base).

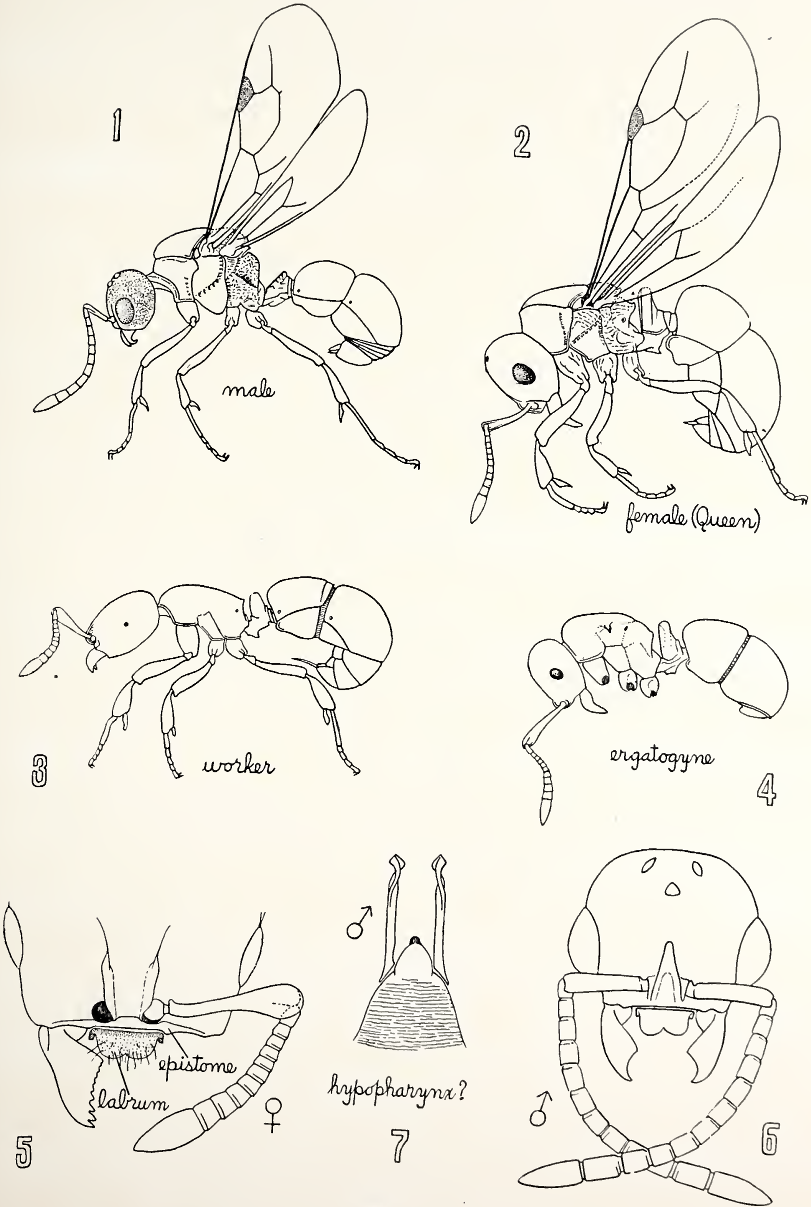
Color of head and body black; mandibles, antennae, and legs brown. Wings with colorless membrane and brown stigmas. (*Croceum* is ferruginous).

See Figures 1, 6, 8, 13, 15, and 21-26 which are drawn from regional material but from other nests than the male type nest.

Proceratium silaceum is a remnant from that time, barely a hundred years ago, when Ohio and Indiana were covered with an almost continuous forest. With the forest cover intact, drainage was much less rapid than now, so that much of the wooded area was more moist the year around. In those areas supporting white and burr oaks this species of ant was probably to be found in every oak log which, at a late stage of decay, had the proper moisture content.

Collection Records

Proceratium silaceum is sparsely listed in the literature because it is a rare ant which is never taken abundantly. Roger described it in 1863 (pp. 171-172), basing his description on one worker, which he lists as from North America. It has subsequently been collected along the eastern and southern parts of the United States.


1
male
2
female (Queen)
3
worker
ergatogyne
4
5
epistome
labrum
♀
♂
hypopharynx?
7
♂
6

Figs. 1-7.

The present paper concerns *P. silaceum* gathered from Ohio, Canada, and Tennessee. The collecting was done between 1930 and 1938, and during this time it was taken 16 times in Ohio, 9 times in neighboring parts of Canada, and 4 times in Tennessee. Most of the collections were made in the region of western Lake Erie over the islands and mainlands which surround Gibraltar island. This territory includes Ottawa County in Ohio and a part of Ontario, Canada. From Ontario the following collections are recorded: Middle Island (7-13-34 C. A. Dennis), Pelee Island (7-25-30 R. Wolf; 8-19-30, 8-23-30, 7-18-31, 8-18-31, 8-25-36 M. T.; 8-25-38 M. E. Amstutz), Point Pelee (8-5-31 C. H. K.). From Ottawa County, Ohio, are the following: South Bass Island (8-14-31 M. T.), Kelley's Island (8-18-35 C. A. Dennis), West Sister Island (7-18-36 C. H. K.), Catawba (7-10-31 S. R. Williams; 7-11-35 M. T.).

Other collections in Ohio show that the ant is rather widely distributed throughout the state. Records are as follows: in north central Ohio from Huron County (8-22-31 C. H. K.), in northeastern Ohio from Ashtabula County (8-29-38 A. E. Headley), in central Ohio from Franklin County (9-1-36 C. H. K.), Delaware County (6-5-38 C. H. K.), and Madison County (9-7-31, 9-25-31 C. H. K.), and in southern Ohio from Adams County (9-1-31 C. H. K.), Pike County (6-14-32 C. H. K.; 2 collections, no date, M. Schramm), and Meigs County (1 collection, no date M. Schramm).

The Tennessee records are from Blount County on the eastern edge of the state (9-15-31, 9-12-32, 9-17-32, 4-21-33 C. H. K.).

Since these scattered records extend over a period of intensive collecting by the authors and include the combined efforts of a number of other people, they tend to substantiate the evidence that *Proceratium silaceum* is truly a rare ant, not abundant in any habitat.

Ecological Distribution

The conditions under which the ants live are remarkably similar. Seemingly they possess very little toleration for variation in habitat. In every case they have been found in logs or stumps large enough to retain moisture, and in such a state of decay that the wood can be picked apart with the fingers or is already in fine, loose, soil-like granules. White oak logs seem to reach this state in the most perfect fashion, and most of the ants have been collected in this wood, but they have also been found in pine, elm, and burr oak logs in similar condition.

The logs must not only be well decayed but they must lie in a place where moisture is plentiful and constantly maintained. Other environmental factors in the surroundings may vary considerably. On Pelee Island and the neighboring mainland of Point Pelee, logs containing nests were found on sand of richly vegetated pine or oak dunes. Here the sand is subirrigated by the lake. Collections were also made from longs lying on loam in woods of various types of vegetation: elm-maple woods on Pelee Island, oak-maple woods on South Bass Island, hackberry woods on Middle Island, and oak-hickory woods at Willard (Huron Co., Ohio). These were usually deep, moist woods, in most cases near a river, lake, or bog. Thus the substratum may vary from sand to loam and the type of vegetation may be quite diverse, but conditions must be such that large logs are kept thoroughly and constantly moist, and the logs must be in an advanced state of decay.

Nest Conditions

One of the aggravating things about collecting *Proceratium* is the fact that frequently a single individual is found, and then no amount of hunting will reveal the nest. In only 16 cases were nests actually found. One such, containing an unusually large colony of 60 workers, 73 males, 1 dealate female, and larvae and pupae, was collected on Pelee Island under rather typical conditions. The large white oak log, lying near the top of a small, completely vegetated white oak dune just back of the sand plain on the south spit of the island, was overgrown with wild grapes and poison ivy and was partially shaded by young trees. It was red and soft enough to be broken easily with the fingers in most places, although it retained its shape throughout. The ants were in an unusually soft part in the upper half of the log. They had small galleries following the annual rings of the wood. The workers were almost the color of the wood, and, since they moved slowly or remained curled up motionless, they were hard to see. The black, active males were quite conspicuous. In the same log were nests of *Ponera coarctata pennsylvanica* Buckley, *Myrmecina graminicola americana* Emery, *Strumigenys pergandei* Emery, *Aphaenogaster fulva aquia picea* Emery and *Camponotus herculeanus pennsylvanicus* De Geer.

Nests seem to be most frequently located in the soft wood which is just stiff enough to retain its shape but which is near an area of loose granular decay. Usually the nest is a small cavity 2.5 to 3 mm. long and .5 to 1 mm. wide with one or more slender galleries leading out from it and extending between the slightly harder circles of spring growth of the annual rings. Colonies are usually small; perhaps the one which contained 28 workers may be considered average.

Larvae and pupae were found from the beginning of the collecting season (July) until its end (September); so no data were gathered as to when they are first produced in the spring or whether they wintered over. Pupa cases are delicate enough that the pupae may be seen within them. They are white and only slightly elongated, not yellow and long as are those of the other two local *Ponerinae, Ponera coarctata pennsylvanica,* and *Stigmatomma pallipes.* They are about 1 mm. wide and 2.5 mm. long. Callows, newly emerged, are a very light straw color. Males and winged females probably emerge near the first of August (our earliest record for collecting them is 8-7-31). They are still in the nest in early September. Workers are entirely hypogaeic and have never been found in the light.

Associated Ants

Other ants, such as *Ponera coarctata pennsylvanica, Myrmecina graminicola americana, Stenamma brevicorne* Mayr, and *Strumigenys pergandei* or *pulchella* Emery, are frequently found associated with *Proceratium silaceum.* The colonies are never actually living together but occur in different parts of the large moist logs which form the preferred niches of these species. However, the associated ants are not nearly so closely restricted in their nesting sites as is *P. silaceum*, since they are found in more varied habitats and are more abundant and widespread. Often ants of a wider range of habitat toleration are also found in the logs: *Camponotus herculeanus pennsylvanicus*, *Aphaenogaster fulva aquia picea*, and *Lasius umbratus mixtus aphidicola* Walsh. The logs are good niches for almost any kind of wood-inhabiting ant except such forms as *Crematogaster* and varieties of *Camponotus caryae* Nyl., which regularly nest in hard, dry wood.

Variations

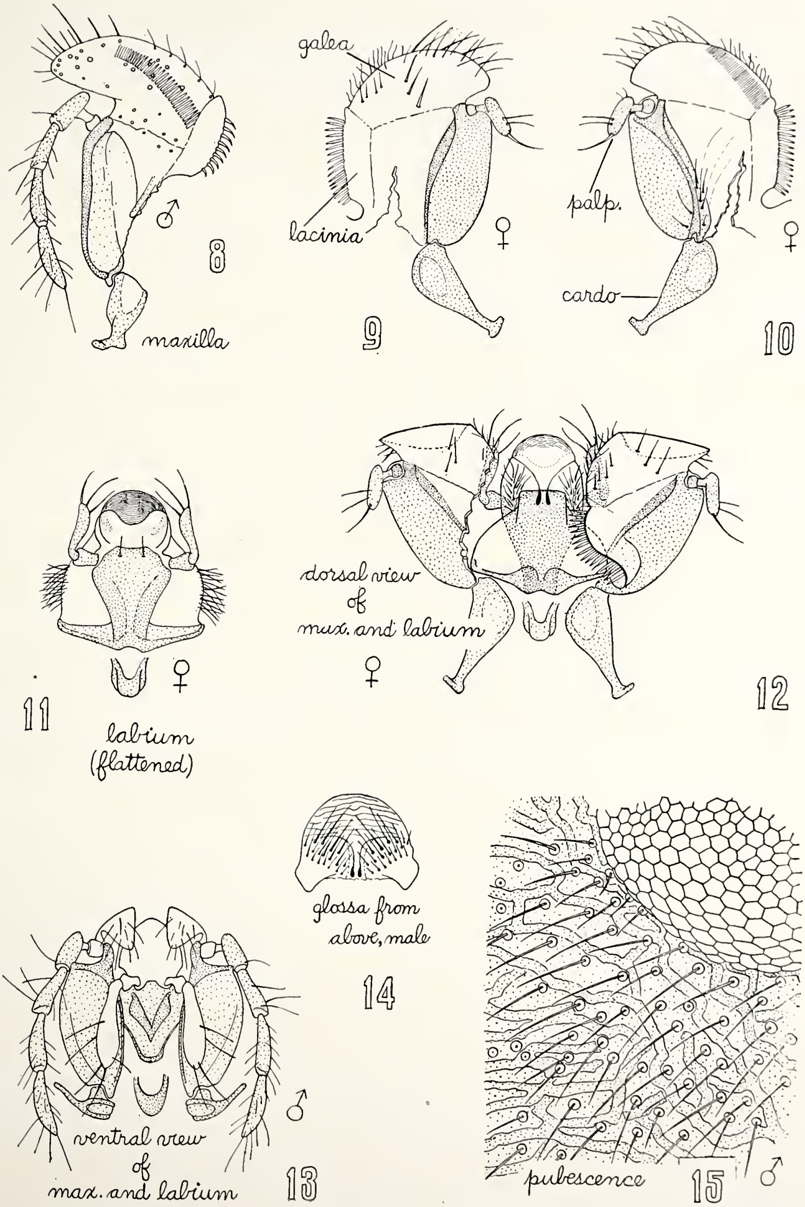
Three collections contained ants which were darker than the others. These were: (1) a large colony of 55 workers with one dealate female and one ergatogyne (Fig. 4), taken by C. H. K., No. 2618 (6-5-38) in Delaware County, Ohio, in a red, rotten white oak log lying in a shady second growth woods beside Big Walnut Creek; (2) a colony of 25 workers and one dealate female, taken at Catawba by M. T. (7-11-35) in a stump, with wood soft enough to come off in layers, lying under dense trees of an oak-walnut woods; (3) a single worker taken at Catawba by S. R. Williams (7-10-31) from unknown habitat. These answer Wheeler's description of *P. silaceum* subsp. *rugulosum* (from Wyandotte, Ind.) in that they are uniformly darker and more opaque than the other *P. silaceum* seen. However, they could not be distinguished by any uniform intensity of rugosity or any definite anatomical variation from the species. Whether they should be considered as being *silaceum* or Wheeler's Indiana subspecies cannot be decided until they are compared with type specimens.

Structure

The normal male, queen, and worker are shown in Figures 1-3. Proceratium belongs to the very primitive subfamily Ponerinae, many of which are distinguished by the groove between segments 1 and 2 of the gaster (abdominal segments III and IV). See Figures 1-4 and 16. The genus is further peculiar in the differentiation of the gaster into two regions. See Figures 16 and 17. Abdominal segments III and IV (Segs. 1 and 2 of gaster) are well developed and form most of the visible abdomen but tucked in the apex of abdominal segment IV is a postabdomen of abdominal segments V to X which usually points cephalad but can be completely retracted into segment IV. This is similar to the anatomy of the higher flies (example, the house fly) but has evolved independently.

The eyes are large in the queen and male but are minute in the almost blind worker (Fig. 3). In the ergatogyne (Fig. 4) they are intermediate in size.

The ergatogyne is not found regularly in Proceratium nests but appears to be one of nature's genetic accidents. The latest evidence (Wheeler, 1937) is that the ergatogyne is a genetic mosaic of the worker and queen castes. We have found these in but one nest, Kennedy coll.,


♂
8
maxilla
galea
lacinia
♀
9
palp.
cardo
♀
10
♀
11
labium
(flattened)
dorsal view
of
max. and labium
♀
12
glossa from
above, male
14
ventral view
of
max. and labium
♂
13
pubescence
15
♂

Figs. 8-15.

No. 2618 (Delaware County, June 5, 1938). This nest contained a normal dealate nest queen, the ergatogyne with undeveloped wing stubs, which is figured (Fig. 4), and two workers with eyes slightly larger than those of other workers but no wing development. In the same nest were 55 normal workers. This was a nest of the slightly larger, darker form which on comparison with types may prove to be *rugulosum* Wheeler (1915). The type material of *rugulosum* was collected by Dr. W. S. Blatchley at Wyandotte, Indiana.

The mouthparts are shown in detail because they are so minute in an ant 2-3 mm. long that they have been little studied and seldom figured for ants so small. Figures 5 and 6 show the labrum, which the ant keeps folded into the mouth. The mandibles of the male (Fig. 6) are without teeth as compared with those of the worker or of the queen (Fig. 5). What is probably a hypopharynx (Fig. 7) dissects out of the floor of the mouth of the male. It may occur in the female castes but was not found.

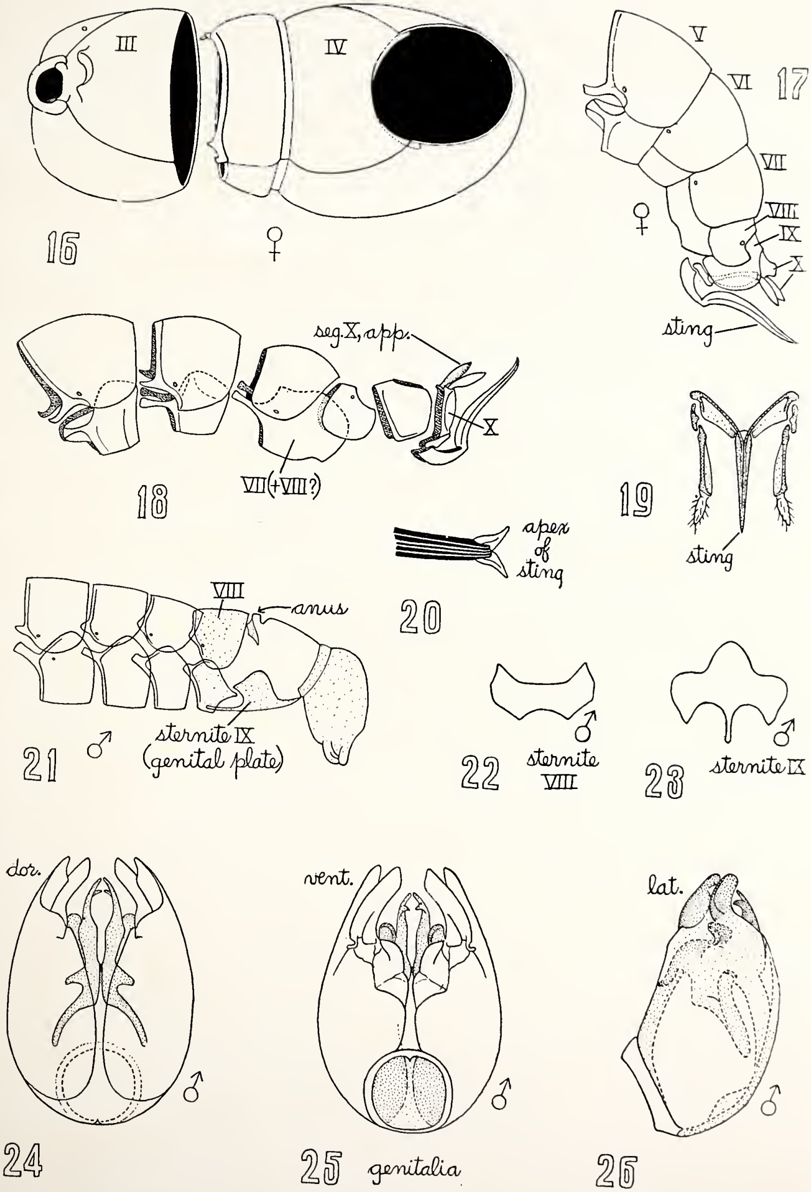
Figures 8, 9, and 10 are views of the maxilla, of male (Fig. 8), and queen (Figs. 9 and 10). The maxillary palp in the male is four-segmented, while in the queen and workers it has one segment. On the galea, revealed by transmitted light, is a comb-like series of sense organs. This is termed the "maxillary comb"; in the male it has 25 to 30 parts, while in the queen there are about 40. In larger ants these organs appear to be rigid hairs lying tight against the inner surface of the galea. Here they appeared to be more deeply embedded and less like free hairs. We have shown them, as seen by transmitted light, in Figures 8 and 10 and did not determine whether they were more closely associated with the internal or with the external surface of the galea. In Figure 9 the maxillary comb has been omitted to show better the hairs on the inner surface of the maxilla.

Figures 11, 12, 13, and 14 show the labium in the male and queen. In both the palpus is two-segmented. The inner surface is well supplied with long bristles (Figs. 11 and 14).

Figure 15 is a view at high magnification of the size of the pubescent hairs, showing their spacing as compared with the size of the ocellae of the compound eye. The area figured is between the eye and the base of the antenna of that side. We have been trying to develop some method of figuring the surface texture, pubescence, longer hairs, etc., of ants, as these items are used so extensively in describing species. The written terms are so susceptible of more than one interpretation. The checking by a figure of these parts against the size of the ocellae of the compound eye is one method of making a more accurate record of size and spacing of the pubescence.

The sting of the female (queen) is shown in Figures 17 to 20. The pair of cercus-like organs are considered appendages of segment X and are not cerci or appendages of segment XI. Before it has been lost by use, the apex of the sting bears a bifurcate membraneous cap (Fig. 20).

Segments VII-X are highly modified in the female. Apparently the sternite is missing from segments VIII, IX and X. The sternite of segment VII is twice as long as those of segments V and VI, which suggests


III
IV
16
♀
V
VI
17
VII
♀
VIII
IX
X
sting
seg. X, app.
X
18
VII (+VIII ?)
19
sting
apex of sting
20
VIII
anus
21
♂
sternite IX (genital plate)
22
sternite VIII
♂
23
sternite IX
♂
dor.
24
♂
vent.
25
genitalia
♂
lat.
26
♂

Figs. 16-26.

that it may be double or a fusion of the sternites of segments VII and VIII. Notice the high position of the spiracle on segment VIII.

In the male (Figs. 21-26) the first highly modified segment is segment IX, where the tergite is reduced to a mere sliver in front of the anus, and the sternite is developed into a genital plate (Figs. 21 and 23). The latter is usually of a slightly different shape for each species of ant but to be studied has to be dissected out of the male. Figures 24-26 show three views of the male genitalia. The internal pair of slender forked parts (Figs. 24 and 25) are probably sagittae. The outermost pair of unstippled prongs are probably stipes.

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The Development of a Second Generation of the European Corn Borer, *Pyrausta nubilalis* Hbn., in Indiana

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When the European corn borer first entered Indiana in 1926, this insect was distinctly a one brooded form. Since that date, occasional traces of a second generation have been noted from time to time, but it was not until 1935 that sufficient second-generation borers were found to indicate a distinct trend toward a definite second brood of economic importance. During the past three years, the number of second generation borers produced has been so great as to become an important factor in corn borer increase. This transition of the borer to a two-generation form will alter several phases of the corn borer problem which up to the past three or four years have been thought of as being practically stabilized.

Pupation

Information on the pupation of the first generation larvae is fragmentary during the period up to 1935. In 1935 the first pupae were found in the field in DeKalb County, in sweet corn, on August 7; in 1936, on July 21; in 1937, on July 20; and in 1938, on July 14. Contrary to the development of pupation among the over-wintering larvae, the pupation of those larvae which provide the second brood occurs rather abruptly and apparently affects only the early larvae of the first generation.

In 1938 in Allen County, second brood pupation began on July 14 and was complete by August 8, a period of 20 days. In 1937, pupation began on July 30 and was complete on August 8, a period of 19 days. These periods, denoting the time when pupae are present in the field, are much shorter than the time required for the over-wintering larvae to pupate.

TABLE I.—Figures Showing the Percentage of First Generation Larvae Which Pupated in Dent and Sweet Corn in DeKalb County in 1938.

Sweet Corn		Dent Corn	
Planting Date	Per Cent of Borers Pupated	Planting Date	Per Cent of Borers Pupated
April 29	16.1	May 6	7.5
May 6	14.1	May 7	7.0
May 7	8.5	May 11	6.3
May 10	2.0	May 21	3.0
May 27	2.0	May 27	1.0
June 6	3.0	June 8	0.0

The fact that only the earliest larvae of the first generation pupate has been rather clearly indicated by the increased proportion of borers which have pupated in early dent or sweet corn fields as compared to the number pupating in later fields which receive only those eggs which were laid late in the first generation moth flight (Table I).

The percentage of larvae pupating to provide a second brood is variable not only in different fields but also in different localities. The highest rate of pupation has been found in early sweet corn fields, these being the locations in which the earliest eggs of the first generation moths are most frequently laid. Exceptionally early and vigorous dent corn fields also frequently show correspondingly high rates of pupation because of the influence of the height of the corn in attracting the first moths for the purpose of oviposition, but few dent corn fields have been examined in which the borers show as high a rate of second generation production as do early sweet corn fields.

The general trend toward an increased rate of second generation production in the more southernly locations of the borers distribution has been shown by examinations of fields from Steuben County southward to Wayne County (Table II).

TABLE II.—Percentage of Borers Pupating in Seven Counties in Indiana From Steuben County in the North, Southward to Wayne County. Fields Selected Were the Earliest Available.

County	Per cent Pupating in Early Sweet Corn	Per cent Pupating in Early Dent Corn	Mean
Steuben	2.10	2.00	2.05
DeKalb	16.10	7.00	11.52
Allen	8.00	14.5	11.25
Adams	8.00	19.5	13.75
Jay	11.11	19.6	15.30
Randolph	18.00	.....	18.00
Wayne	19.64	.....	19.64

The rate of pupation in Steuben County was 2%, and in Wayne County it was 19.64%. Other counties located between these localities showed intermediate degrees of second-brood production. These figures, while varying somewhat in individual fields, tend to indicate a transitional area in central Indiana in which the European corn borer is changing its seasonal development to provide for a whole or partial second generation.

Moth Flight and Emergence

The use of light traps during the past four years, to determine the period of actual moth flight, has shown a variable period of flight of first- and second-generation moths, both from the point of view of the time of flight and the duration of flight. The beginning of first-generation flight has varied from June 7 in 1938 to June 28 in 1935, and the end of the first flight has varied from July 16 to July 23 during the same years. The duration of flight was longest in 1936, when moths were captured at lights over a period of 37 days.

The second-brood flight has varied in its first appearance from July 26 in 1938 to August 4 in 1937, and the duration of active flight in those years when sufficient moths were captured to indicate a well defined second brood has varied from 20 days in 1937 to 47 days in 1938. Weather conditions which favor or inhibit the length of life of the moths has made the flight periods either very short or, as in 1938, very long. Since emergence was complete on August 8 in Allen County, where the light

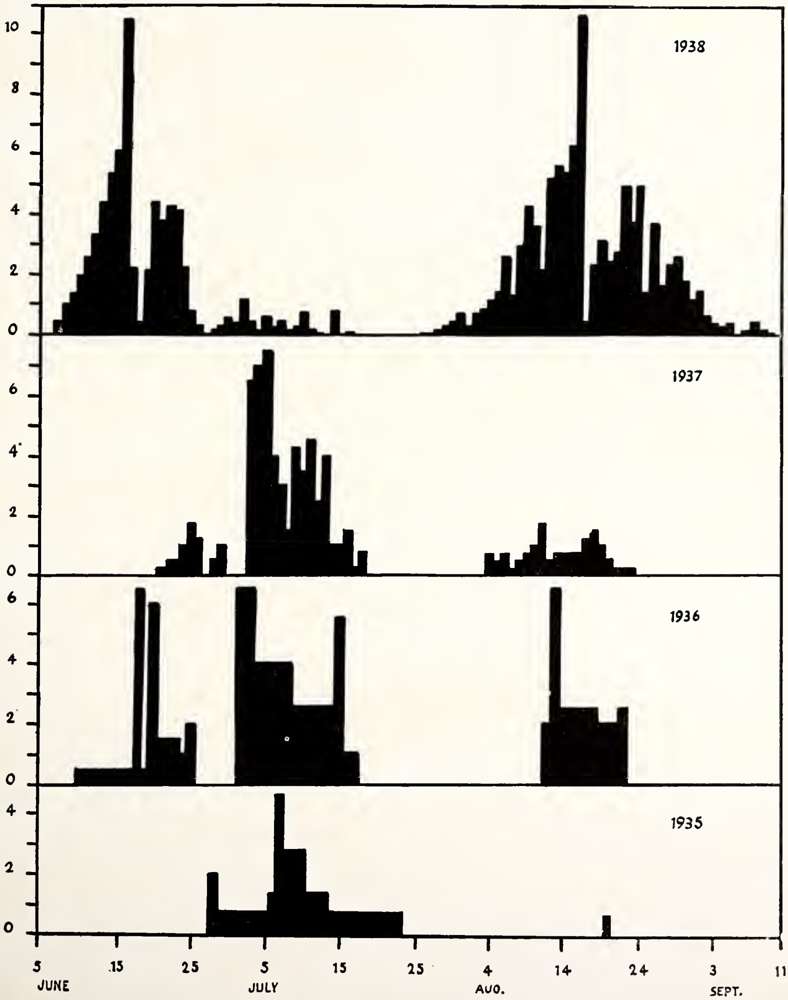

Fig. 1. Trend of moth flight as determined by light trap captures; 1935, 1936, 1937, moths per trap; 1938, moths per trap divided by two.

traps were situated in 1938 and where emergence was being observed, individual moths must have been in flight for a period of at least 34 days.

The proportion of first- and second-generation adults caught in light traps has varied from one second-generation moth to 23 first-generation moths in 1935, from one to 2.31 in 1936, and from one to 4.35 in 1937; and in 1938 the proportion of second brood adults to first generation was reversed and was 2.64 to one (Fig. 1). These figures do not necessarily indicate more moths in flight during the second than during the first generation, as the moths were in flight for a longer period of time during the second brood and the distance from which these moths drifted in to the lights could not be determined. With the longer period of flight after the completion of emergence, larger numbers undoubtedly drifted in from greater distances than in the first brood. In the first generation, moth flight ended 12 days after the completion of moth emergence, while in the second brood, moths continued to fly for 34 days after the last record of moth emergence in the field. Years of early first-generation moth emergence tend to show a higher degree of second-brood production by the European corn borer than do those years in which the emergence of the first brood has been delayed by seasonal climatic conditions.

Winter Mortality

The winter mortality of second-generation borers will be variable from year to year, depending on the stage of development in which the larvae go into the winter. This depends on the time at which the eggs are laid and the seasonal conditions in the fall which will permit the larvae to become mature. In 1935, second-generation larvae did not become mature before cold weather, and the winter mortality of second-generation borers averaged 98% in DeKalb County. During 1936 and 1937, moth flight and oviposition were complete by August 20, and the borers became full grown by cold weather. During these years the winter mortality was no greater than among first-generation larvae and was about normal. During the 1938-1939 season, a heavy winter mortality of second-generation borers may be anticipated as egg laying continued to September 11, and borers resulting from such late eggs will have little chance of becoming mature enough to pass the winter successfully.

Host Preference

So far as is known at the present time there has been little tendency for the second-generation moths to select host plants other than corn for oviposition. A single host other than corn was found during 1938 to be infested by the second-generation borers; this was gladiolus. Late corn is preferred to early corn by the second-generation, and many late fields carry higher borer populations, as a result, than do early fields. Populations of four plantings of dent corn, in experiments at Auburn during 1938, had populations ranging from 14 borers per 100 plants in corn planted on May 12 to 46 borers per 100 plants in corn planted on June 8. This condition was first noted in sweet corn plantings made in 1936, when sweet corn planted in five plantings between May 7 and June

14 had the following borer populations per 100 plants: May 7, 27.19; May 14, 17.02; May 28, .88; June 7, 0; and June 14, 21.48. Extremely early and extremely late plantings tend to carry the heaviest borer populations. This is particularly true of those fields in the southern area of infestation.

Discussion

The development of a second brood of corn borers in Indiana is important from the point of view of several factors. Heavy flights of second brood moths tend greatly to build up over-wintering populations and provide an increased abundance of borers for the succeeding season. Late-planted corn, which heretofore has been practically immune from corn borer, will be, and is being attacked. While the greater part of the second generation of borers became full grown too late in the season to reduce greatly the yields of dent corn, late sweet corn may be damaged to a severe extent. The additional flight of moths, which occurs when weather conditions are normally more conducive to longer life than earlier in the season, will undoubtedly hasten the spread of the borer to new territory and tend to build up populations more rapidly on the margins of the known infested areas. The possibility of an increase in the number of host plants is also an important consideration from the point of view of the damage the corn borer will do to such hosts and also from the greater difficulties encountered in effecting a satisfactory control where infestations might occur in host plants other than corn.

Radiation of *Drosophila melanogaster* with Low-Intensity Ultra-Violet Light for One Complete Generation. I. Effect on Crossing-Over in the Second Chromosome

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Introduction

Considerable work has been done concerning the effects on Drosophila of treatment with X-rays, heat, and radium. This includes production of mutations and modifications of the rates of non-disjunction and crossing-over.

In recent years the effect of ultra-violet radiation has been investigated in some degree. Altenburg studied the production of mutations by unfiltered ultra-violet radiation. Promptov induced mutations by monochromatic ultra-violet radiation. Rifenburgh modified crossover rates by treatment with monochromatic ultra-violet light. All these investigators used relatively heavy doses for short periods.

Since no work had been published on the effect of radiating Drosophila with ultra-violet light for long periods, this work was undertaken to study the effect of unfiltered radiation for a complete generation on crossing-over in the second chromosome of Drosophila melanogaster

Review of Literature

I. Effect of X-radiation.—Mavor (1923) reported from a series of experiments on X-radiation that X-rays caused a decrease in crossover values between White and Miniature either by inhibiting crossing-over or by increasing double crossovers.

Later Mavor and Svenson (1924) investigated the effect of X-rays on crossing-over in the second chromosome. Treated females heterozygous for Black-Purple-Curved were backcrossed to recessive males with the following results: (1) crossover value between Black and Purple 3.77% in controls and 16.67% in the experimentals, (2) crossover value between Purple and Curved 17.38% in controls and 30.58% in the experimentals. This was a very significant increase in crossing-over in the case of the X-rayed mothers.

Muller (1925) published results of work with X-radiated autosomes. He found in both long autosomes a regionally differentiated susceptibility to X-rays, with the maximum susceptibility in the morphologically differentiated portion at or near the spindle-fiber attachment. The second and third chromosomes reacted similarly—that is, with an increase of crossing-over in this region.

II. **Effect of Radium.**—Plough (1924), working with treated females heterozygous for Black-Purple-Curved backcrossed to pure recessive males, found that the beta and gamma rays of radium caused an increase in crossing-over.

III. **Effect of Heat.**—Plough (1917) reported results from an experiment on the effects of temperature and environment. Extreme heat and cold, acting upon females up to the time of hatching, caused a decided increase of crossover percentage in the second chromosome for the first ten day broods. He found no effect of high and low temperature on crossing-over in the first and third chromosomes.

He (Plough 1921) studied the effect of heat on flies heterozygous for autosomal genes. The following results were obtained: (1) there was no significant increase in the percentage of crossing-over in the second chromosome as a result of the exposure of developing eggs to high temperature; (2) in the third chromosome there was an increase in the region of the spindle-fiber attachment only; (3) crossing-over varied with the age of the female but in those regions only which showed a reaction to temperature.

Stern (1926) raised experimental females at 30° C. and controls at 25° C. He obtained an increase in percentage to 16 in the experimentals against 11½ in the controls. This was in the Bar-Bobbed region of the first chromosome, which is near the attachment of the spindle-fiber.

Schwab (1935) made a further study of effect of temperature on crossing-over. Under high temperature there was increased recombination in the third chromosome which was found to be concentrated between Scarlet and Pink (the area of the spindle-fiber attachment) and spreading with high decrement to the adjacent regions. This result agrees with those reported by Muller for X-rays and by Bridges for age.

IV. **Effect of Ultra-Violet Light.**—In this laboratory Rifenburgh (1935) treated virgin females, heterozygous for Black-Vestigial-Brown, with monochromatic ultra-violet light and backcrossed them to Black-Vestigial-Brown males. With radiated adults, he obtained a slight increase in crossover percentage near the spindle-fiber attachment of the second chromosome. In the case of treated eggs and young larvae, there was a decrease in crossover percentage.

General Methods

The source of ultra-violet light for the following experiments was a General Electric Sun Lamp (S_2 Model K). In this lamp, the ultra-violet rays are produced by gaseous mercury heated to incandescence by a tungsten filament within a bulb of special glass. A silver-colored shield placed below the bulb reflects and diffuses the light so that the radiation is nearly uniform over a fairly wide area.

The radiated generation was reared in 100 cc. beakers filled to within an inch of the top with Purdue medium (Rifenburgh, 1933). A thin film of yeast was allowed to grow on the surface of the cultured medium before the flies were placed in the beakers. Since the medium tended to shrink from the sides of the containers, water was added at frequent intervals. This prevented the females from laying their eggs in the crevices around the edge of the medium. Thus, the eggs were laid on the exposed surface. This assured radiation for every egg. Cellophane, held in place by rubber bands, was used for a covering. In the controls, a glass Petri plate in addition to the cellophane was used to shield the flies from the ultra-violet rays.

Since the temperature was increased by the lamp, a small fan was used which cooled the air around the beakers and kept the temperature down to approximately 27° C., which was 2° C. higher than room temperature.

Parents treated under the lamp and those used for controls were taken from the same stock bottles so that they would be of the same age, parentage, and physiological condition.

The female parents were pure Black-Vestigial-Brown virgins, whereas the males were taken from the Wild stock. The flies were mated, one pair to each beaker, were allowed to recover from etherization for a few hours, and then were placed under the lamp. They remained in the beakers until pupae appeared, then they were removed.

The offspring were collected at eight-hour intervals in order to insure virginity of the females. These females (wild in phenotype and heterozygous for Black-Vestigial-Brown) were backcrossed to males from pure stock and pairs were placed in regular wide-mouth mating bottles containing yeast-treated medium. These parents were allowed to remain in the bottles for four days after which they were removed.

The offspring of this backcross were examined, classified, and counted until eighteen days after mating.

From the data so collected, crossover percentages were computed.

Results

1. **Experiment 8.**—Virgin females homozygous for Black-Vestigial-Brown were mated, in beakers as described above, to males from the pure Wild stock and allowed to recover from etherization for a few hours. These beakers then were placed under the ultra-violet lamp at a distance of 37 inches. The parents were removed as soon as pupae appeared. When offspring emerged, the heterozygous Wild females were backcrossed to homozygous untreated Black-Vestigial-Brown males. The results of these mating are shown in Table I. From these results were calculated the crossover value which are shown in Table II and Table III.

2. **Experiment 9.**—This differed from Experiment 8 in two respects: first, the distance was increased to 47 inches; second, the room temperature during the second generation was about 27° C. instead of 25° C. as in Experiment 8.

The observed results are shown in Table I and the computed results in Table II and Table III.

Combined results of experiments 8 and 9 are shown in the same tables with the uncombined results.

TABLE I.—Emergence Record of Backcrosses by Phenotypes

	Experimentals			Controls		
No. of Experiment	8	9	8+9	8	9	8+9
Wild	3838	751	4589	4073	751	4824
Black-Vestigial-Brown	3558	633	10191	3706	655	4361
Black	691	164	855	530	135	655
Vestigial-Brown	608	224	720	454	101	555
Black-Vestigial	1541	112	1765	1387	260	1647
Brown	1728	338	2066	1548	293	1841
Black-Brown	177	34	211	87	20	107
Vestigial	168	31	199	88	11	99
Totals	12309	2287	14596	11880	2226	14106

TABLE II.—Crossover Percentage Between Black and Vestigial Loci. (Region of Spindle-fiber Attachment)

Exp. No.	Experimentals			Controls			Difference	D / P.E.(diff.)
	No. ♀♀ tested	Population	Crossover % B to V	No. ♀♀ tested	Population	Crossover % B to V		
8	58	12309	13.36±.207	70	11880	9.76±.272	3.60±.28	13
9	16	2287	14.91±.445	12	2226	11.99±.46	2.92±.65	4.1
8+9	74	14596	Increase 13.59±.196	82	14106	Increase 10.10±.057	3.49±.20	17.1

Map Distance=18.5 (Morgan 1932).

TABLE III.—Crossover Percentage Between Vestigial and Brown Loci. (Remote Region)

Exp. No.	Experimentals			Controls			Difference	D / P.E.(diff.)
	No. ♀♀ tested	Population	Crossover % V to Bw	No. ♀♀ tested	Population	Crossover % V to Bw		
8	58	12309	29.36±.278	70	11880	26.18±.270	3.18±.39	8.22
9	16	2287	27.42±.629	12	2226	26.24±.629	1.18±.89	.132
8+9	74	14596	29.05±.241 Increase	82	14106	26.18±.244 Increase	2.87±.34	8.36

Map Distance=37.5 (Morgan 1932).

Discussion

In nearly every published record there has been reported an increase in crossing-over produced by treatment with X-rays, radium, heat, and ultra-violet light. The increase has occurred largely in the region of the spindle-fiber attachment (the region which is most susceptible to the effects of radiation).

In the sex chromosome, Mavor found that X-rays caused a decrease in the remote region, but he studied no near region in this chromosome. For the second chromosome he agrees with the others. Plough, Schwab, and Stern found that heat caused an increase in the region of the spindle-fiber attachment. In the Purdue Laboratory, an increase in crossover percentage was produced by ultra-violet radiation between the Miniature and Bar loci which is near the region of the spindle-fiber attachment. An increase also occurred in the remote region in treated individuals in this laboratory (unpublished work).

In the third chromosome some X-radiation and heat caused an increase in the near region (the region of greatest susceptibility).

In the second chromosome heat, radium, and X-rays caused an increase of crossing-over in the region of the spindle-fiber attachment. In the Purdue Laboratory experiments have shown a marked effect of ultra-violet radiation on increase in crossing-over.

Data obtained in this experiment indicate a definite increase in crossing-over percentage due to ultra-violet radiation in the second chromosome, the most striking increase being in the region of the spindle-fiber attachment. Statistical analysis made by dividing the difference by its probable error indicates that there is no question of these results being significant, factors of 17 and 8 being obtained whereas most statistical consciences require but 3.

Probably, in regard to modifying crossover values, ultra-violet radiation should be classed in importance with X-rays, radium, and heat.

Summary

The purpose of the experiments was to determine the effects of unfiltered ultra-violet radiation for a complete generation on crossing-over in the second chromosome of *Drosophila melanogaster* and specifically in the two regions limited by the Black, Vestigial, and Brown loci.

1. Definitely greater crossover values were found in the treated individuals than in the controls.

2. There is no doubt of the difference being significant, since it was more than 17 times its probable error in the Black-Vestigial region and over eight times its probable error in the Vestigial-Brown region.

3. These results are in agreement with those observed by investigators working with other kinds of radiation, who found an increase in crossing-over in treated flies, this being greater in regions near the spindle-fiber attachment than in remote regions.

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Radiation of *Drosophila melanogaster* with Low-Intensity Ultra-Violet Light for One Complete Generation. II. Effect on Crossing-Over in the First Chromosome

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Introduction

To date no work has been published indicating the effects of long-time ultra-violet radiation on crossing-over in the first chromosome and this work was undertaken in order to discover, if possible, these effects.

Previous Work Concerned with the Effect of Radition on Crossing-over in the First Chromosome

Mavor **(1923)** found a decrease in crossing-over in the White-Miniature region treated with X-rays.

Mavor **(1929)** treated females with X-rays in order to discover the resulting effects on non-disjunction and crossing-over. The females which were heterozygous for White-Long and Eosin-Miniature were radiated while still in the pupa stage. The anterior portion of the body of a number of females was exposed in one instance, the posterior portion of a number of others, and the entire body of others. Unradiated females were used as controls. He found that crossover values between the White and Miniature loci were significantly reduced in the offspring of the flies which were exposed entirely to the effect of X-rays and also in the flies which were treated posteriorly.

Investigators using first chromosome factors had found that the crossover values were reduced here in contrast to the increase found in the autosomes. Stern **(1926)** pointed out that the factors used by these workers were located at a distance from the spindle-fibre attachment and that if crossover increases were not found in the remote (from the spindle-fiber attachment) regions of the autosomes, then one should not expect increases in crossover values for the factors in the distal regions of the heterosomes. Accordingly, he exposed eggs heterozygous for Bar and Bobbed factors to high temperatures (30° C.) until the time of hatching, when they were transferred to 25° C. The offspring of the females exposed to high temperatures showed a significant increase in crossing-over (8.5 times the probable error) when compared to the controls which were kept at a constant temperature of 25° C. This increase disappeared about nine days after exposure. Stern explains the drop in crossover values by assuming that high temperature produces its effects upon crossing-over at the oögonial stage and does not effect germ cells that are in the oöcyte stage. Eggs laid seven or eight days after the removal of the females from 30° C. temperature had not yet reached the susceptible oögonial stage at the time they were subjected to the high temperatures.

Methods

The methods used were similar to those of Rifenburgh and Paradise (1938), a General Electric S2 sun lamp being used from the time of mating the P_1's until the F_1's emerged, at a distance of forty-eight inches.

The female parents were virgins from the stock of Yellow-White-Miniature Drosophila. The male parents used were of pure Bar stock. One male and one female were put into each beaker and after the flies had been given sufficient time to recover from the effects of etherization, the beakers were placed under the lamp. These parents were allowed to remain in the beakers until larvae appeared and then were removed.

The offspring were irradiated during their entire life history until the time of mating. The female offspring were heterozygous for all four pairs of factors and Bar in phenotype, but, since the factors were sex-linked, the male offspring were homozygous recessive.

The irradiated Bar females were removed at 8-hour intervals in order to assure their virginity. The males were discarded or used for back-crossing.

The females were back-crossed to Yellow-White-Miniature males which were the quadruple recessives, Bar being a dominant factor.

The parent flies were left in the original bottles for four days, then transferred to a new bottle for another four-day period, and then re-transferred to a third bottle for still another four-day period. It was expected that more offspring would be produced by one female in a series of bottles than she would produce normally if left in only one bottle for the egg-laying period.

The offspring were counted on the eleventh, fourteenth, and seventeenth days after the parents were placed in the bottles. Classification was made as to phenotype and sex.

Results

Eighty-six matings of experimentals were made. Fifty pairs were transferred at the end of four days to new bottles where each remained for another four-day period before being transferred to a third bottle.

Fifty-five control matings were made of the non-irradiated Bar females. Forty pairs were transferred to second and to third bottles.

The 176 experimental bottles produced 18,174 flies which were distributed among the phenotypes as follows:

4263	Bar
5526	Yellow-White-Miniature
116	White-Miniature
93	Yellow-Bar
2618	Miniature
1067	Yellow-White-Bar
1368	Wild
697	Yellow-White-Miniature-Bar
2	White-Bar
7	Yellow-Miniature
292	Miniature-Bar
2001	Yellow-White
0	White-Miniature-Bar
17	Yellow
6	White
1	Yellow-Miniature-Bar
18174	

The 135 control bottles produced 2793 flies which were distributed among the phenotypes as follows:

688	Bar	3	Yellow-Miniature
825	Yellow-White-Miniature	47	Miniature-Bar
11	White-Miniature	337	Yellow-White
19	Yellow-Bar	0	White-Miniature-Bar
396	Miniature	4	Yellow
161	Yellow-White-Bar	3	White
205	Wild	0	Yellow-Miniature-Bar
94	Yellow-White-Miniature-Bar		
0	White-Bar	2793	

Crossover percentages for the three regions of the chromosome were calculated. The values are tabulated in Tables I-II-III.

TABLE I.—Crossover Percentage in the First Chromosomes of Females Between Yellow and White Loci

Experimentals			Controls			Difference	$\frac{D}{P.E._{(diff.)}}$
Number of Matings	Total Population	Crossover % Y to W	Number of Matings	Total Population	Crossover % Y to W		
176	18174	1.33± .0513	135	2793	1.432±.1524	Decrease .100±.163	.615

Map Distance 1.5 Morgan (1932).

TABLE II.—Crossover Percentage in the First Chromosome of Females Between White and Miniature Loci

Experimentals			Controls			Difference	$\frac{D}{P.E._{(diff.)}}$
Number of Matings	Total Population	Crossover % W to M	Number of Matings	Total Population	Crossover % W to M		
176	18174	32.981± .744	135	2793	33.962	Decrease .981± .910	1.08

Map Distance 34.6 (Morgan 1932).

TABLE III.—Crossover Percentage in the First Chromosomes of Females Between Miniature and Bar Loci (The Region of Spindle-fiber Attachment)

Experimentals			Controls			Difference	$\frac{D}{P.E._{(diff.)}}$
Number of Matings	Total Population	Crossover % M to B	Number of Matings	Total Population	Crossover % M to B		
176	18174	24.111± .068	135	2793	21.124± .402	Increase 2.981± .408	7.321

Map Distance 20.9 (Morgan 1932).

Discussion

The results of this experiment show a slight decrease in crossover percentage between the Yellow and White loci. This decrease was not significant, being less than its probable error. This Yellow-White region has a map distance of only 1.5, and, because of its extreme shortness, it must be rather resistant to changes in amount of crossing-over.

In the White-Miniature region the experimentals show a decrease in crossing-over as compared with the controls, but, again, the decrease is not significant. Rifenburgh (1935) used these same loci and found that ultra-violet light of high intensity caused an increase in crossing-over in offspring of females radiated as pupae but a decrease in offspring of females radiated as adults.

Working with X-rays, Mavor found a decreased crossover percentage for the White-Miniature region. He attributed this decrease to a crossover inhibitor developed by the X-rays or to increased double crossing-over which he could not measure since his experiment involved only two loci.

The increase in crossing-over between the Miniature and Bar loci is somewhat unexpected in the light of Mavor's and Rifenburgh's work. However, neither of these workers used a region so near the spindle-fiber attachment as this. The increase is significant, being 7.3 times the probable error. These results indicate that the effects of radiation must be much the same as in the autosome.

Early workers used loci at the left end of the first chromosome and found decreased crossover percentages, leading them to believe that the sex chromosome and the autosomes were opposite in reaction to the effects of X-radiation. Later it was found that the increase in crossing-over in the autosomes was limited to the region near the spindle-fiber attachment and that the regions near the ends of the autosomes were resistant to changes resulting from radiation.

Muller, Plough, and Schwab each have conducted experiments with third chromosome characters which range from the Roughoid locus at 0.0 to the Claret locus at 100.7, and they agree in finding an increase of crossover percentage near the attachment of the spindle-fiber only. Mavor, Muller, and Plough each subjected flies with second chromosome characters to radiations, and again each found crossover increases near the center of the chromosomes only.

Stern used Bar-Bobbed factors of the first chromosome in measuring effects of temperature on crossing-over in this region, which is near the attachment of the spindle-fiber. He found a significant increase, and this led him to believe that the crossing-over mechanism was susceptible to change near the point of the spindle-fiber attachment only.

The present work with ultra-violet irradiation involving loci scattered almost the entire length of the first chromosome seems to corroborate the work of both Mavor and Stern. Regions distant from the spindle-fiber attachment showed decreases in crossing-over that were, however, not significant, whereas the region nearest the spindle-fiber attachment showed an increased crossover percentage.

Comparison of the results reported in this paper with work of Mavor, Muller, Plough, Rifenburgh, Rifenburgh and Paradise, and Stern seems to indicate that, in general, electro-magnetic radiations cause an increase in crossing-over in the various chromosomes which is most pronounced near the points of spindle-fiber attachment.

Summary

This work was undertaken in order to discover the effects of long-time low-intensity ultra-violet radiation on crossing-over in the first chromosome of *Drosophila melanogaster*. The regions tested were between the Yellow and White, White and Miniature, and Miniature and Bar loci.

1. No significant effects on crossing-over between the Yellow and White and between the White and Miniature loci were found.

2. Crossing-over in the Miniature-Bar region was significantly increased.

3. These results agree with the results of other workers with other types of radiation, who found that crossover increase occurred principally or entirely near the point of spindle-fiber attachment.

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A Note on the Occurrence of the Spotted Turtle, *Clemmys guttata* (Schneider) in Indiana

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In May, 1938, a male specimen of the spotted turtle, *Clemmys guttata,* was collected from a small creek near Logansport, Indiana. According to Cahn **(1937)**, the geographic distribution of this species extends from the Atlantic seaboard westward to Illinois and Wisconsin. Hay **(1891)** reported its occurrence in Indiana "only in the northern portion among the numerous lakes, streams and swamps found there." He mentioned Dr. G. M. Levette reporting it first from Kendallville but did not give the source of his information. Two specimens were taken by members of the Indiana Academy of Science at Lake Maxinkuckee in 1891. Other collectors mentioned by Hay were Dr. V. Gould, Rochester, and Dr. Baur at English Lake. The present report is the only record of a spotted turtle collected south of Lake Maxinkuckee. The westernmost limits of its distribution appears to be in southern Wisconsin and near the Indiana-Illinois boundary. Higley **(1889)** reported it from Walworth County, Wisconsin; and more recent records by others indicate its common occurrence in the southern part of this state. Cahn collected two specimens from the western end of Wolf Lake, Cook County, Illinois.

The present specimen agrees with Cahn's description of *C. guttata* with but one exception. He described the claws as follows: "All five of the digits of the fore limb with claws; hind limbs with only three digits bearing claws." In our specimen the five digits of the fore limb and four digits of the hind limb bear claws. Cahn gave measurements of only two females; but since his description of the species was based on the study of several individuals, the difference in claws does not seem to be a sexual character. According to Cahn, the number of orange spots on the carapace is about sixty. Sixty-one were counted on the present specimen.

The following table affords a comparison of the writer's specimen (3) with two spotted turtles (1 and 2) described by Cahn **(1937)**. All measurements are in millimeters.

Carapace		Plastron			Head	Tail		Sex
Length	Width	Length	Width	Depth		Total	A-T	
(1) 109	87	99	71	40	16	26	20	female
(2) 114	76	95	68	40	16	31	25	female
(3) 113	104	85	50	45	16	26	20	male

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Banding Studies of the Blue Jay

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In central Indiana the Northern Blue Jay *(Cyanocita cristata criatata)* is a conspicuous and common bird of town and country. It frequents the vicinity of habitations, nesting during April, May, and June, and appears to remain in the immediate neighborhood the year round, for it is about equally abundant both winter and summer. Whether it really migrates more or less and how much it wanders in a given locality can be determined definitely only by banding studies. These problems as they relate to the birds of this immediate region, together with certain remarks on longevity, form the basis of this paper.

In the 14 years, from December, 1924, to October, 1938, 253 blue jays have been banded at the two stations we have maintained at West Lafayette, Indiana. Most of these were banded in our yard on the western outskirts of the town. From nests in the immediate vicinity 18 young birds were banded and 27 adults were caught and banded at a substation[1] a quarter of a mile away. Traps were maintained at the substation only during the years 1931, '32, and '33, and then for only four months of each year, from the middle of March to the middle of May and the middle of September to the middle of November.

Of the 253 blue jays banded, 45 show a total of 68 returns (captures three months or more since previous captures). These 45 birds returning are 17.8%, and the 68 returns 27% of the 253 banded. Total recaptures were much higher. As the U. S. Biological Survey reports only 6.2% returns on birds of all species banded since 1920, it would seem that our blue jays have given a relatively high percentage of returns on which to base conclusions.

An examination of Table I shows that the number of birds banded in any one year varies greatly. It was highest in 1928 when 38 were banded, even though in this year there were five months, February, March, August, October, and November, in which no new birds were banded. The smallest total is for 1933 when six only were banded in five months. There is no year in which jays have been banded every month, but in 1932 only January and September were skipped. Of returns, 1929 shows the fewest with one only, and 1931 and 1932 the most with eleven and nine, respectively, while 1928 yielded five.

The distribution of total captures and returns throughout the year is interesting. Jays have been banded every month of the year, the spring and summer months predominating, with April showing the largest number, a total of 52, and February the fewest with four. Bandings for January and December each exceed those for March, October, and November. Recaptures are distributed over every month of the year but are least, one each, for August and September, which were high in bandings. May and June have the most returns with April only slightly behind. February recaptures are five, one more than bandings for that month. The number of traps in operation varied through the years, but no definite relation is seen between the traps in operation and birds caught. If the year is divided into winter and summer calling April, May, June, July, August, and September summer months and January, February, November, and December winter months and not including March and October, as birds taken in these months might be hangovers from winter or summer, there are 21 birds which show returns for summer only, six for winter only, and 19 for both winter and summer. Further analysis of the returns shows that 16 birds were recaptured two or more times, ten of these both winter and summer.

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[1] For description of this substation see Proc. Indiana Acad. Sci. 40:369-370.

A possible explanation of the large numbers banded in April and May and the many returns for April, May, and June may be that during this season, while the birds are busy with nesting duties and feeding time is limited, they find it easier to take the convenient supply of food at the traps than to forage.

Of the total returns, 13 were of birds found dead, and the rest were recaptured at one of our stations, except in a single instance when one individual, banded May 14, 1931, was caught April 7, 1932, by D. R. Burtsfield at his station on North Main St., about a mile from ours.

TABLE I.

Year	Jan.			Feb.			Mar.			April			May			June			July			Aug.			Sept.			Oct.			Nov.			Dec.			Totals		
	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.	Bnd.	Ret.	Rep.
1924																																		2			2		
1925	3				1		1	1		5		2				X			X			X						5			1						15	2	0
1926	2	1		1	1		2						2	1		X			X			X			1									3			11	3	0
1927	1	2														1			X			9		1	8		8										19	2	8
1928	1	1								2			14	1	3	9	3	1	1			X			10		1							1			38	3	5
1929	2						1			8			3				1	2	7	1	5	6		2	4												31	2	9
1930										2	1	1	4	3		X		1	X			X			2						1			1			10	4	2
1931	1				1		3			12	4	46	7	3	13	1			1	1								1	1				2	1	1		27	11	61
1932				1			1			2	3		10	2	2	3	1	1	3	1	1	4					1	1	1		2	1		1			28	9	5
1933										2			2			1	3		X			X						1				1			1		6	5	0
1934					1					2			3			3	1		6		2	1										1		1	1		16	4	2
1935		1					1			3	1					2	2		2																		9	4	0
1936	4		1	1	1	3				3			2						1			2	2	1			1					1			2		14	6	6
1937							1	2			1		2	1		2			6	1	2										3	2		1		1	15	7	3
1938	5	2	1	1		1				1			3	2								1			1				2								12	6	2
Totals	19	7	2	4	5	4	10	3	0	42	10	49	52	13	18	22	11	5	27	4	10	23	2	4	26	0	11	8	4	0	7	6	2	11	5	1	253	68	103

* Station not in operation.

This station and another maintained for a time nearby were the only other stations in or near West Lafayette. None of the dead birds were found more than a mile from our banding station. Among the data on range are records of nine birds captured at both the home station and the substation a quarter of a mile away. Of 18 young birds banded from nests, only one gave a return in a later year. This bird, B-327931, was banded in the yard of a neighbor, 50 yards from our traps, May 21, 1932, recaptured in both June and July of that year and returned to our traps December 29, 1933, and again December 14, 1934.

Referring to Table II, it is seen that of the 19 birds caught both winter and summer, 12 were caught more than twice, and eight re-

TABLE II.

Bird	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
338355	15/27	......	18/25	......	......	......	......	......	......	......	......	11/24†
306020	18/25†	14/25	......	......	......	......	......	......	......	......	......	......
284364	11/26	......	......	......	21/26	......	......	......	......	29/25†	......	......
284362	......	3/26	......	......	......	......	......	......	......	7/25†	......	......
284365	......	3/28	......	......	......	......	......	......	......	......	10/25†	......
284357	8/27	19/26†	......	......	......	......	......	......	......	......	......	......
520654	......	......	......	......	......	23/28	......	26/27†	......	......	......	......
520655	......	......	......	......	......	6/28	......	27/27†	......	......	......	......
520658	......	......	......	......	......	4/28	......	29/27†	......	......	......	......
520667	......	......	......	......	17/28	......	......	......	6/27†	......	......	......
526944	......	......	......	......	6/28† 30/30 11/31	9/29 5/32	......	......	......	......	......	......
652113	......	......	......	......	......	......	9/29	......	17/28†	......	......	......
A-401907	......	......	......	21/29†	27/31	......	......	......	......	......	......	......
A-401916	......	......	......	30/29† 30/30	......	......	......	......	......	......	......	......
A-401923	......	......	......	......	12/29† 29/30	......	......	......	......	......	......	......
A-401954	......	......	......	24/31	......	......	9/29†	......	......	......	......	......
A-401920	......	......	......	......	7/29† 8/31	10/30	......	......	......	......	......	......
A-401958	......	......	......	23/31 3/32	27/30	1/33	21/29†	......	......	20/31	......	......
A-401959	......	......	......	16/31	......	......	24/29†	......	......	......	......	......
A-309436	......	1/31	......	7/30†	......	......	......	......	......	......	......	......
A-345403	......	......	......	24/30† 9/31	......	......	......	......	......	......	......	......
A-413644	4/31†	......	......	14/32	......	......	......	......	......	......	......	......
374904	......	......	......	18/31†	......	9/33	......	......	......	......	......	......
374906	27/35	......	......	20/31†	17/32	......	......	......	......	......	......	......
374913	......	......	......	24/31†	......	......	......	......	......	......	......	2/31
374920	......	......	......	......	1/31† 25/32	......	......	......	......	......	......	......
374928	......	......	......	7/32	14/31†	......	......	......	......	......	......	......
A-379185	......	......	......	......	......	26/35	26/31†	......	......	......	......	......
A-379200	......	......	......	......	......	......	9/32	......	......	......	......	29/31†
A-379183	......	......	......	1/32	......	......	......	......	......	23/31† 7/32	20/33	......
B-327915	......	21/34	30/37	1/35	5/32†	......	......	......	......	......	......	......
B-327931	......	......	......	......	21/32†	......	......	......	......	......	......	29/33 14/34
B-362856	......	......	......	......	......	15/33	......	17/32†	......	......	......	......
B-362872	......	......	......	......	21/37	......	......	......	......	......	3/32†	......
B-386453	......	......	......	......	......	......	......	......	......	15/33†	2/34	......
34-340132	......	......	......	......	......	19/35	25/34†	......	......	......	......	......
34-340136	......	15/36	......	......	......	......	30/34†	......	......	......	......	......
34-340158	......	......	31/35†	......	......	......	......	......	......	......	22/36	......
34-372931	20/36† 1/38	......	30/37	......	1/38	......	......	......	......	......	26/36	......
34-372933	24/36†	......	......	13/37	......	......	9/37	......	......	24/38	......	23/36
34-372943	......	......	......	4/36†	......	......	......	10/36	......	......	......	......
34-372954	......	......	......	......	3/36†	......	......	11/36	......	......	20/37	......
36-327228	7/38	......	......	......	31/37†	......	......	......	......	......	......	......
36-327286	19/38	28/38	......	......	......	......	22/37†	......	......	......	17/37	......
28-300302	......	......	......	......	4/38	......	......	......	......	9/38	10/37†	19/37

†Date of banding.

turned in four different months, one having six captures. This latter bird, A-401958, was banded July 21, 1929, at the home station, and recorded as immature. On May 27, 1930, it was taken at the substation and was recaptured at this station several times in April, 1931, beginning on the 23rd. That fall two more records were made at the same place, October 22 and November 4. The following spring it was there again on April 3 and 17, but on June 12 it was taken at the home station. It was found dead about half way between the two stations June 1, 1933. It had been caught in our traps 17 times before it died at the age of at least four years.

Other interesting returns, as shown in the table, include the following:

34-372931, banded January 20, 1936, returned December 26, 1936, March 30, 1937, January 1, 1938, and May 1, 1938.

34-372933, banded January 24, 1936, returned December 23, 1936, and April 13, 1937, and repeated July 9, 1937.

36-327286, banded July 22, 1937, returned November 17, 1937, and repeated January 19, 1938, and February 28, 1938.

B-327915, banded May 5, 1932, returned February 21, 1934, April 1, 1935, and March 30, 1937.

384362, banded October 29, 1925, repeated January 11, 1926, and returned May 21, 1926.

From the fact that several individuals have been taken in both winter and summer months, as shown in Table II, it is evident that at least a portion of the blue jay population of this region is resident throughout the year. The relatively few bandings for fall would seem to indicate that there is no great influx of migrants from the north. While the high bandings for April might be interpreted as a northern spring migration, the few captures for March and the first half of April, together with the fact that the jays frequently begin nesting by, or before, the middle of April, would indicate little such migration. Just three of our jays show records of captures both early spring and late fall only. Some of the published banding records[2] give a few instances of jays banded in north central states during late spring, summer, or early fall and recovered during the winter in states farther south. These are all from localities about 1.5 degrees north of our region. There are also a few records from central Indiana and northern Ohio of autumn wanderings of 15 to 40 miles. Only by the analysis of many additional banding data can the question of migration be definitely answered.

Some idea of the natural length of life of blue jays may be obtained from these records. The longest period between banding and last capture is for bird B-327915 banded May 5, 1932, as an adult. It returned three times, the last capture being March 30, 1937. This, at the very least would show the bird to be six years old. When last captured it seemed to be in perfect condition and weighed 85.3 grams against 81.3 grams at banding. Another bird, B-362875, banded November 3, 1932, was found sick and died May 21, 1937; so it must have been five years old or more. As there is no telling how old it was at banding, the death may have been a result of old age. Three other returns demonstrate ages of at least five years.

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[2] Lincoln, Returns from banded birds, 1923 to 1926, U. S. Dept. Agr. Tech. Bull. No. 32, 1927; Bird banding notes, Vol. 2, No. 16, 1938. (Mimeog. by U. S. Bur. Biol. Surv.)

Results of these banding studies so far seem to justify the following conclusions for the region under discussion:

1. The blue jays seem in large part to be permanent residents. For our birds there is no positive evidence of any migration and some evidence that there is little or none.

2. Blue jays as a rule probably do not range far either for feeding or nesting, though there may be wandering during the year over an area up to a mile in diameter.

3. Individual blue jays are known to have lived at least six years and be in good condition at that age, and four are known to have lived five years or longer.

Additional Data Concerning Human Intestinal Parasite Infections in Indiana

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Introduction

The question of the status of human parasite infections in Indiana is one which yet remains to be answered satisfactorily. Only meagre information is available concerning the incidence of parasite infections in this region and their importance in reference to public health. In a former report on the subject (Headlee, 1937), the available literature was reviewed, and certain case reports of parasite infections not in the literature were mentioned. The parasites listed in that report were *Plasmodium* (causal organisms of malarial fevers), *Endamoeba gingivalis*, *Trichomonas vaginalis*, *Diphyllobothrium latum* (the fish tapeworm of man), *Enterobius vermicularis* (the pinworm or seatworm), *Filaria bancrofti*, *Trichinella spiralis* (the pork worm), and among the arthropods, *Pediculoides ventricosus* (the grain mite), and the larva of the sheep gad fly *Oestrus ovis*. For the most part this information was gained from case reports, and there were no valid data concerning the incidence of these parasites in the general population of the state. No information was available concerning the incidence of intestinal protozoa. Reasons for this lack of information were set forth, data concerning the human parasite infections of neighboring regions were cited, and the hypothetical status of human parasite infections in Indiana was presented. It was concluded that "Indiana may have a considerable incidence of human parasite infections, particularly in the southern part of the state, but definite proof of this probable condition awaits more detailed studies than have at present been made."

During the past two years an attempt has been made to gain further information concerning human parasite infections in Indiana, particularly in reference to the incidence of intestinal parasites. The additional data now available have been obtained primarily from surveys conducted at Longcliff State Hospital, Logansport, Indiana, and among students at Purdue University. Other data have been obtained from the examination of individuals not included in the two groups just mentioned.

Materials and Methods

The only accurate method of detecting and diagnosing infections of intestinal parasites is by a microscopic examination of fecal material from the individual in question, which examination will reveal the ova of worms and the cysts and trophozoites of protozoa, if present. There are certain exceptions to this rule. Only a small percentage of infections with the pinworm, *Enterobius vermicularis*, are detected by fecal examinations, due to the fact that the female worms do not lay eggs while they are in the intestine. The gravid females migrate from the bowel and burst when they reach the exterior, and eggs are scattered in the perianal and perineal regions. To diagnose this infection, perianal scrapings should be made and examined microscopically. In still other cases, if and when the larger worms, or portions of them, are passed in the stool, they may be examined and identified. However, an individual may have a parasite infection for years before it is detected in this latter manner.

The present data were obtained by microscopic examination of fecal specimens. The specimens were collected in cardboard containers and examined within 24 hours after collection. Both unconcentrated and centrafugalized, concentrated preparations were examined from each fecal specimen. A smear was made by comminuting a portion of fecal specimen in a few drops of physiological saline solution on a 40 x 75 mm. slide. A cover glass was placed over a portion of the smear, and to the remaining portion a drop of Donaldson's iodine was added before covering. This preparation was then examined under the microscope. A portion of the stool was comminuted in tap water, strained through gauze, and centrifuged. A portion of this concentrate was used to make an iodine-stained preparation for further examination. In this manner both trophozoites and cysts of protozoa and eggs and larvae of helminths can be observed in their natural and fixed conditions.

In 1936 Kmecza (1939) examined 1,200 patients of Longcliff State Hospital, Logansport, Indiana, for intestinal parasites. The patients of the hospital were all from northern Indiana, i.e., they had established their residence in the northern part of the state at least a year previous to admission to the hospital. Therefore, the results of this survey are a good indication of the incidence of infection with various species of intestinal parasites for this locality. Of the 1,200 patients examined, 565 were males and 635 were females. Among this group of patients 622, or 51.8%, were harboring one or more species of protozoa, helminths, or both. Six hundred and eighteen patients, or 51.5%, were infected with one or more species of protozoa; 20 patients, or 1.7%, harbored helminth infections, and 14 patients, or 1.2%, were parasitized with one or more species of protozoa and one species of helminth. The species of protozoa and helminths noted and the percentage incidence of each were as follows: *Endamoeba histolytica*, 0.2; *Endamoeba coli*, 31.3; *Endolimax nana*, 37.7; *Iodamoeba bütschlii*, 3.2; *Giardia lamblia*, 1.8; *Enterobius vermicularis*, 1.6; and *Diphyllobothrium latum*, 0.1.

During the past two years, primarily during the spring of 1937, a number of students of Purdue University were examined for intestinal parasites.[1] One hundred and forty-seven of these students indicated that their residences were in Indiana, and the data obtained will add to our knowledge of the incidence of intestinal parasites in this state. Of this number, 118 were males and 29 were females, ranging in age from 17 to 36 years. Of these students, 64, or 43.6%, were infected with one or

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[1] The writer wishes to acknowledge with thanks the cooperation of Dr. S. J. Miller, director of the Purdue University Student Health Service, and members of his staff.

TABLE I.—The Incidence of Human Intestinal Parasites Among Individuals of Various Indiana Population Groups.

POPULATION GROUP	LONGCLIFF STATE HOSPITAL						STUDENTS OF PURDUE UNIV.						MISCELLANEOUS						TOTAL					
SEX	M		F		M and F		M		F		M and F		M		F		M and F		M		F		M and F	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Endamoeba histolytica	2	0.4			2	0.2	3	2.5	2	6.9	5	3.4	1	12.5			1	7.7	6	0.87	2	0.2	8	0.6
Endamoeba coli	221	39.1	154	24.3	375	31.3	19	16.1	7	24.1	26	17.7	1	12.5	2	40.0	3	23.1	241	34.9	163	24.4	404	29.7
Endolimax nana	249	44.1	203	32.0	452	37.7	39	33.1	8	27.6	47	32.0	2	25.0	1	20.0	3	23.1	290	42.0	212	31.7	502	36.9
Iodamoeba butschlii	27	4.8	11	1.7	38	3.2	1	0.08			1	0.07							28	4.1	11	1.6	39	2.9
Giardia lamblia	14	2.5	8	1.3	22	1.8	4	3.4	1	3.5	5	3.4							18	2.6	9	1.3	27	2.0
Chilomastix mesnili									1	3.5	1	0.07	1	12.5			1	7.7	1	0.1	1	0.1	2	0.15
Ascaris lumbricoides													1	12.5			1	7.7	1	0.1			1	0.07
Trichocephalus trichuris							1	0.08			1	0.07							1	0.1			1	0.07
Enterobius vermicularis	10	1.8	9	1.4	19	1.6							3	37.5	1	20.0	4	30.8	13	1.9	10	1.5	23	1.7
Hymenolepis nana													1	12.5			1	7.7	1	0.1			1	0.07
Diphyllobothrium latum			1	0.2	1	0.1															1	0.1	1	0.07
Total with infections of Protozoa	335	59.3	283	44.6	618	51.5	51	43.2	13	44.8	64	43.6	2	25.0	3	60.0	5	38.5	338	56.2	299	44.7	687	50.5
Total with infections of Helminths	10	1.8	10	1.6	20	1.7	1	0.08			1	0.07	5	62.5	1	20.0	6	46.2	16	2.3	11	1.6	27	2.0
Total with infections of both Protozoa and Helminths	9	1.6	5	0.8	14	1.2	1	0.08			1	0.07	1	12.5			1	7.7	11	1.6	5	0.7	16	1.2
Total Infected	335	59.3	287	45.2	622	51.8	51	43.2	13	44.8	64	43.6	6	75.0	4	80.0	10	76.9	392	56.7	304	45.4	696	51.2
Total Examined	565		635		1200		118		29		147		8		5		13		691		669		1360	

more species of protozoa, and one, or 0.07%, with one species of helminth. The species of protozoa and helminth noted and the percentage incidence of each were as follows: *Endamoeba histolytica,* 3.4; *Endamoeba coli,* 17.7; *Endolimax nana,* 32.0; *Iodamoeba butschlii,* 0.07; *Giarardia lamblia,* 3.4; *Chilomastix mesnili,* 0.07; and *Trichocephalus trichuris,* 0.07. Although these students had visited the Student Health Service for medical attention, only a small percentage of these were seeking relief from gastro-intestinal disturbances. In some instances the gastro-intestinal illness was proved to be due to, or enhanced by, parasite infection; in others it was not due to the presence of parasites.

Additional data may be added from the results of examinations of 13 other individuals residing in Lafayette and vicinity. These individuals sought examinations because they were desirous of knowing whether or not they were harboring infections. Thirteen persons were examined, 8 males and 5 females, ranging from 2 to 45 years of age.

Ten, or 76.9%, were infected with one or more species of protozoa, helminths, or both; 6, or 46.2%, harbored helminths, and 5, or 38.5%, had infections of protozoa. The parasites noted and percentages of incidence were as follows: *Endamoeba histolytica,* 7.7; *Endamoeba coli,* 23.1; *Endolimax nana,* 23.1; *Chilomastix mesnili,* 7.7; *Ascaris lumbricoides,* 7.7; *Enterobius vermicularis,* 30.8; and *Hymenolepis nana,* 7.7.

Combining the data from these three groups, the following percentage incidences of parasitism were noted; *Endamoeba histolytica,* 0.6; *Endamoeba coli,* 29.7; *Endolimax nana,* 36.9; *Iodamoeba Butschlii,* 2.9; *Giardia lamblia,* 2.0; *Chilomastix mesnili,* 0.15; *Ascaris lumbricoides,* 0.07; *Trichocephalus trichuris,* 0.07; *Euterobius vermicularis,* 1.7; *Hymenolepis nana,* 0.07; and *Diphyllobothrium latum,* 0.07. Of the 1,360 individuals examined 687, or 50.5%, were infected with one or more species of protozoa; 27, or 2.0%, were infected with helminths, and 16, or 1.2%, were infected with both protozoa and helminths, while 696, or 51.2%, were harboring infections of protozoa, helminths, or both.

The data for these three groups of individuals and the combined groups are presented in Table 1.

Discussion and Conclusions

The data presented in this paper give us a more complete picture of the incidence of human intestinal parasites in Indiana than has previously been available. However, more data are necessary before a complete picture can be presented. To date only a relatively small group of persons have been examined, and they were not representative of the general state population. Those individuals examined by one survey were representatives of a select group living under excellent sanitary conditions. The second group, representing university students, may be considered as a sample of the population group that has been more fortunate in regard to sanitation and general economic conditions. Therefore, a representative sampling of the population of the state has not yet been obtained, only a very few having been examined from the group representing the lower economic and social levels. Also, only a very few children were examined, and in this group we would expect a higher incidence.

The incidence of *Endamoeba histolytica*, 0.6% for the general group is very low. Craig (1934) estimated that from 5 to 10% of the people of the United States were carriers of this parasite. The incidence of this parasite among the students, (3.4%) more nearly approaches this estimated figure.

If perianal scrapings had been examined, it is quite certain that the incidence of *Enterobius vermicularis* would have been considerably higher. The incidence of all parasites would no doubt have been higher if more than one examination of each person had been made.

The case of *Diphyllobothrium latum* infection was of interest because of an unusual clinical history, reported in detail by Headlee, Kmecza, and Cable (1939). This is the fifth case of diphyllobothriasis to be reported from Indiana.

The data presented justify the previous conclusion that "Indiana may have a considerable incidence of human parasite infections." The present data indicate that the incidence of pathogenic species is low, but, as examinations are made from a more representative part of the population, this incidence will probably increase.

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A Preliminary Survey of the Surviving Species of Caudata of Vigo County and Vicinity

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This report on the surviving species of Caudata in Vigo County and vicinity is based upon a rather extensive survey made over a period of some six years. The specimens were identified by descriptions in Pratt's *Manual of the Land and Freshwater Vertebrates of North America.* Specimens about which there was doubt of correct identity were sent to Dr. Karl P. Schmidt of the Field Museum, Chicago, for confirmation.

Some three or four thousand specimens have been collected, representing 12 species. Observations have been made at some length on the life habits of these species both in their native habitats and under controlled conditions in the laboratory.

Certain definite changes appear to have occurred in the fauna of this region since a report was made by W. S. Blatchley, 1899. Some species reported common in this area at that time now appear to be quite rare; other species seem to be increasing noticeably in numbers.

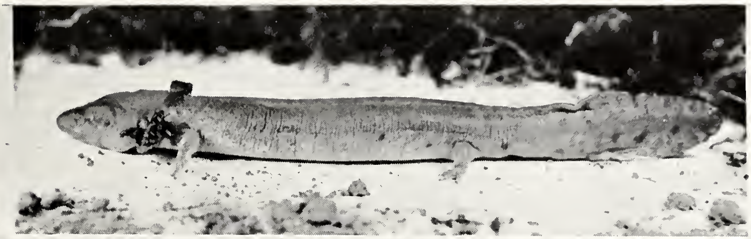
This survey should not be considered either complete or final. Further research may disclose additional facts about this group, and it is hoped that new species will be added to the list already compiled.

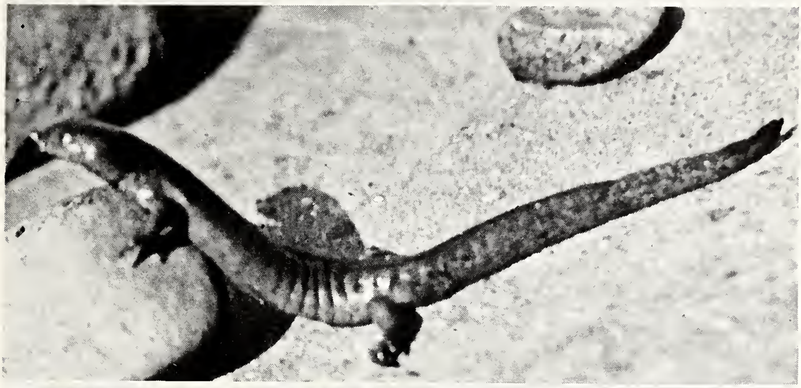
Necturus maculosus, Mud-puppy or Water Dog. (Fig. 1.) This comparatively large salamander is rather common in the Wabash River and occurs sparingly in some of the smaller streams of Vigo County. Its fondness for earthworms, crawfish, and minnows has earned notoriety for the species as an inveterate bait-stealer. It also feeds on insects and their larvae, mollusks, and occasionally on smaller salamanders.

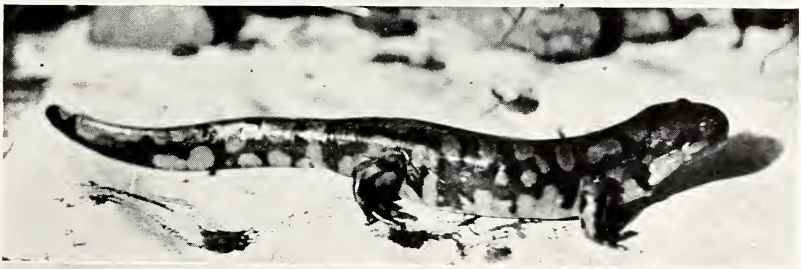
Frequenting the deeper portions of the stream as it does, the Mud-puppy is seldom taken except on fish-lines. It is interesting that the species is seldom or never taken during the warmer months of the year, but it is often caught during the cool seasons of late fall and early spring. The bodies of specimens taken in the fall appear gaunt and lean, but in the spring they often appear plump and well laden with meat. This body condition may indicate a period of fast during the hot summer months followed by heavy feeding during the winter. Also it may help to explain why the Mud-puppy is so seldom taken by fishermen during the hot weather.

The largest specimen taken measured 16½ inches in length, although the average size is about 12 inches.

Ambystoma texanum, Small-mouth Salamander. (Fig. 2.) The Small-mouth Salamander abounds in the Wabash River lowlands but is seldom found elsewhere in the county. In a series of approximately two thousand specimens collected, wide color variations were noted: light







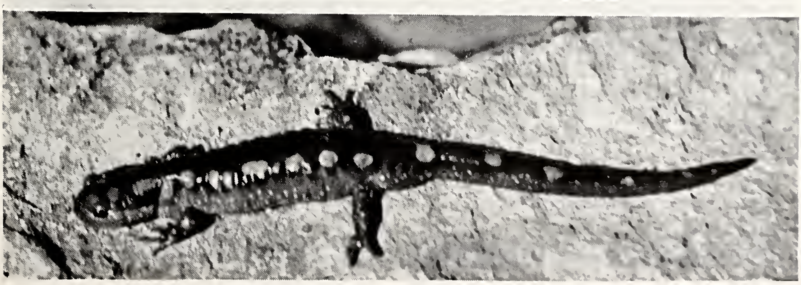


Fig. 1. *Necturus maculosus,* Mud-puppy, Water Dog.
Fig. 2. *Ambystoma texanum,* Small-mouth Salamander.
Fig. 3. *Ambystoma tigrinum,* Tiger Salamander.
Fig. 4. *Ambystoma maculatum,* Spotted Salamander.

silvery gray, greenish slate, brownish, lead colored, and almost jet black in some instances. Some were mottled; others were immaculate. An albino was collected April 17, 1937.

The average length of adults appears to be about five or six inches; but one giant specimen, which was taken from a cellar in Terre Haute, measured nine and one-half inches. It probably reached this unusual size because of exclusion of certain natural enemies, notably the garter snakes.

When attacked, this salamander has a faculty, which it holds in common with many other species, of exuding an irritating, distasteful secretion from pores in the skin. The garter snakes and water snakes do not seem to be the least bit offended by this material, but a Copperhead in the laboratories showed signs of distress after biting one of these specimens and refused to engulf it until it had been washed free of the odious secretion.

Ambystoma tigrinum, Tiger Salamander. (Fig. 3.) The Tiger Salamander is the species most often seen in Terre Haute, probably because of its predilection for wells, cellars, open vaults, and other such places in the city. It also frequents the river lowlands but is much less common there than the Small-mouth Salamander. The coloration consists of irregularly arranged yellowish or tan spots superimposed upon a dark brown or blackish body. Some specimens collected measure as much as nine inches in length. The Tiger Salamander feeds voraciously on earthworms, insects, and mollusks, as well as frogs and smaller salamanders.

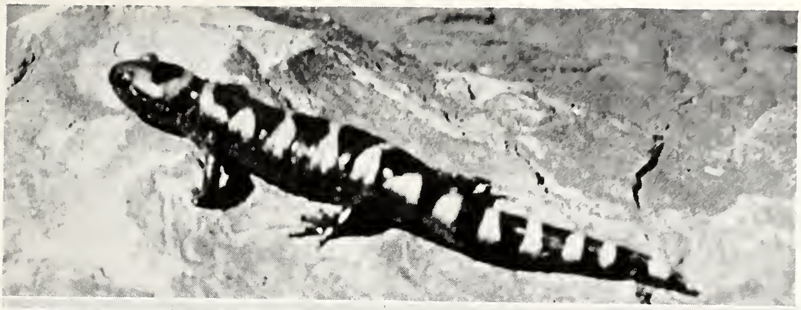
Ambystoma maculatum, Spotted Salamander. (Fig. 4.) The Spotted Salamander seems to be rare in this area; only two specimens have been collected to date. To the contrary, this species was formerly reported rather common in Vigo County by W. S. Blatchley in 1899.

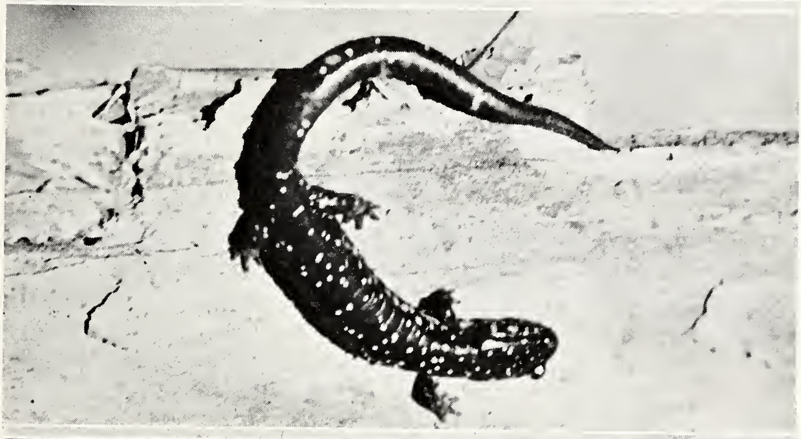
The Spotted Salamander may be easily distinguished from the Tiger Salamander by the two dorsal longitudinal rows of bright canary yellow spots and the uniform bluish-slate colored sides.

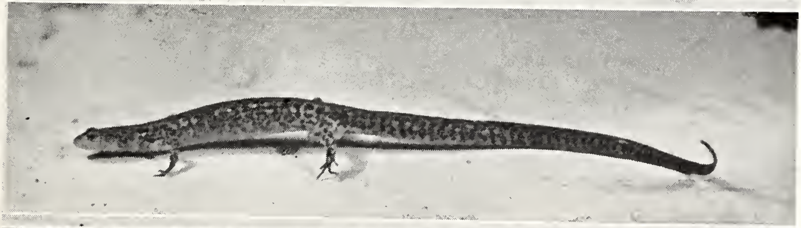
Ambystoma opacum, Marbled Salamander. (Fig. 5.) This strikingly marked salamander is rare in Vigo County and vicinity. Only two specimens have been collected during the survey. One was taken from near North Terre Haute during 1935, and the other specimen was found in a damp woodland near Youngstown in September, 1937. The Marbled Salamander can be distinguished unmistakably from any other species in our area by means of color alone. The body color is jet black with about 14 transverse silvery white bands on the back. The species is small and seldom exceeds four and one-half inches.

Plethodon glutinosus, Slimy Salamander. (Fig. 6.) The Slimy Salamander is common in moist woodlands throughout Vigo County but is not found in the annually flooded river bottoms. It seems to be almost entirely insectivorous and feeds readily on termites, caterpillars, and beetles. Coloration consists of a shiny, anthracite-black body, more or less sprinkled with small white dots.

This is probably the largest of the Plethodontidae in Indiana. Specimens have been found which measured seven inches in length.







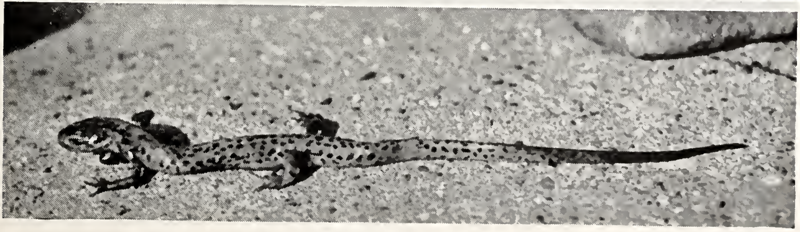


Fig. 5. *Ambystoma opacum,* Marbled Salamander.
Fig. 6. *Plethodon glutinosus,* Slimy Salamander.
Fig. 7. *Eurycea longicauda,* Long-tailed Salamander.
Fig. 8. *Eurycea lucifuga,* Cave Salamander.

Plethodon cinereus, Red-back Salamander, Gray Salamander. Both the red-backed and gray phases occur in Vigo County. The largest specimen examined was from North Terre Haute. It measured five inches in length and one-third of an inch in diameter. The food of this species, so far as it can be determined, consists of small insects.

Plethodon dorsalis. Although not yet recorded, it is very probable that this species does occur in Vigo County, since specimens have been collected from the neighboring counties, Parke, Clay, Owen, and Brown.

It may be distinguished from the Red-back Salamander by the dentate borders of the dorsal stripe, sometimes resembling a chain of rhombs. It feeds on small insects.

Eurycea bislineata bislineata, Two-lined Salamander. The Two-lined Salamander is common in most small woodland streams and spring overflows. Coloration consists of a yellowish tan body with two dorsal longitudinal stripes. This species seldom exceeds four inches in length and is insectivorous in feeding habits.

Eurycea longicauda, Long-tailed Salamander. (Fig. 7.) The Long-tailed Salamander is apparently rare in Vigo County, since only three specimens have been taken during the survey. One of these was a young specimen, which was taken in the river lowlands where it doubtless had been carried by the spring floods.

The Long-tailed Salamander may be recognized easily by the yellowish body color, definitely mottled with black, and by the vertical bars of black on the tail. It seems to prefer a limestone or shale habitat and exhibits a fondness for insects and other small aquatic life.

Eurycea lucifuga, Cave Salamander. (Fig. 8.) Although not yet recorded, future collecting may possibly show the Cave Salamander to be a resident of Vigo County. Many specimens have been collected in Owen County at McCormick's Creek State Park. The Cave Salamander seems to prefer the cool, dark, damp caves and sinkholes so frequently found in limestone formations; other species of the same genus are seldom found in these dismal locations.

The orange-red body, sprinkled with black dots, makes this salamander one of the prettiest of Indiana forms.

Siren intermedia, Mud-eel. Two specimens of this odd salamander were collected in the spring of 1938. One was found in a flooded field at North Terre Haute, and the other specimen was taken on a fish-line in the Greenfield Bayou in southern Vigo County.

The Mud-eel is distinct from all other salamanders in Indiana in that it possesses only the anterior pair of legs. The eel-like body and external gills are also strong points for identification. The food consists of earthworms, crustaceans, and mollusks.

Although *Cryptobranchus alleganiensis*, the Hellbender, is reported by Glenn Cowgill, Vigo County game warden, to be rather common in the Wabash River south of Terre Haute, as yet no specimens have been added to our collection.

Further investigation, it is hoped, may also disclose *Triturus viridescens*, the Newt, *Ambystoma jeffersonianum*, and *Hemidactylum scutatum*, all of which were reported by W. S. Blatchley in 1899.

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Notes on Indiana Fresh Water Sponges

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When a zoology teacher mentions sponges his students at once think of the ordinary commercial sponges, for the excellent reason that these are the only kind most of them have ever seen or heard of; they are quite unaware that sponges may be found in streams and fresh-water lakes in many places. Apparently but few have been interested in these simple animals, and this, added to the fact that they are of no economic importance, has tended to keep them in obscurity.

This is a preliminary report on some work that has been done in investigating the sponges in some of the lakes and streams of two counties thus far—Kosciusko and Wabash. In this area sponges are to be found most numerously in the lakes and their immediate outlets. Only a very few have been found in streams other than lake outlets. As an example, Eel River was explored rather thoroughly for about a mile and in that distance but two small specimens were found, the largest being about a quarter of an inch in diameter. In every case, with the exceptions noted above, when smaller streams were investigated, not a single specimen was found. The reason for this is evidently the amount of sediment carried by these streams; for there are records from streams in other parts of the state. Since sponges depend for their food and oxygen on water that must pass through rather minute pores, any sediment will manifestly prove a serious handicap to them.

But some of the lakes tell a different story. A few seem to be without sponges, as diligent search has failed to disclose any; but in others they are more or less abundant. In the author's experience, a good way to determine their presence in a given lake is to examine the outlet of the lake. Here one is very likely to discover many specimens of the kinds to be found in the lake itself, on submerged sticks, on stones or gravelly bottoms, on roots that project into the water, and sometimes on various water weeds. It is interesting to note that though many specimens may be found in such a location, farther down the stream the matter of sediment seems again to become the dominant factor, and sponges are not to be found. Because of the sedimentation that occurs in the lake, the water there and in its outlet furnishes an environment that is usually very satisfactory for sponges. If they are found in a given lake they are often abundant in some parts of it, while in others that look as well adapted they may be entirely absent. In the lakes examined, most specimens were found on rushes growing in shallower water and very rarely on other submerged objects, evidently because the latter are rarely free from algae or sediment of some sort. For some reason they seem to prefer the cylindrical stems to triangular ones and at times they are found almost exclusively on rushes that have been cut or broken off at about the water level. It is possible that the action of wind on the rushes may explain this behavior. Potts suggests that they will be found rarely or not at all in water containing considerable amounts of lime; but many found on rushes show the presence of lime deposits in and about them in quantities sufficient to be quite noticeable, thus demonstrating that they are able to exist in the presence of this substance.

Pretty generally the specimens found are of the "encrusting" type. The only exceptions are those found growing on roots or matted weeds. Because in growing they follow the numerous branches of these, they are found in a few cases to be somewhat "massive" but rarely of the size of a finger. They vary considerably in surface texture and somewhat in appearance, but those found are rarely branched. Occasionally they have slight elevations, but these would scarcely be called branches. Most sponges are some shade of tan, though, if they have grown where they are exposed to direct sunlight, they are usually green shading to tan or whitish as they reach the more shaded part of their support. They have a distinctive odor which, once it is recognized, is sometimes of use in distinguishing doubtful specimens from certain algal growths at time of collecting. This, coupled with the use of a small pocket lens rarely leaves one in doubt as to the identity of a given specimen.

Potts reports observing sponges throughout the winter and in the South they seem to be regularly perennial, but none have been found in the area explored. They have been found on rushes by the middle of June, but by mid-November they usually have completely disappeared except for gemmules, sometimes interspersed with a few spicules. The gemmules seem to adhere to the base on which they grew and start the sponge anew the following summer. Most species do not form gemmules until October 1 or later, though some have been found as early as the fore part of August. In one or two species, notably *Spongilla aspinosa*, it is difficult to find gemmules at any time, but it is evident that they must form or that these are perennial.

In Vol. XIV of the Illinois Natural History Survey, Smith names seven species as being reported from this state, viz: *Spongilla fragilis, Ephydatia crateriformis, Heteromeyenia argyrosperma, H. repens, H. ryderi, Carterius latitenta* and *C. tubisperma.* In addition he states that *Ephydatia fluviatilis* or *E. mülleri* should be included, though he is unable to determine which from the reports, as these two are often confused. Not all of these have been found in the area examined but five species have been identified, three of which are to be found in his list. *Spongilla fragilis* and *Carterius tubisperma* are numerous as is also *Ephydatia mülleri;* and if one follows some authorities and divides this last into two species—*mülleri* and *japonica*—both are to be found. Two species not listed by Smith are to be found here—*Spongilla aspinosa* and *S. lacustris,* though neither is as common as the other three. It is hoped that wider search will reveal a number of other species.

Indiana Mastodons*

Marcus Ward Lyon, Jr., South Bend

There are records of mastodons from 46 of Indiana's 92 counties. Most of the records are based on rather fragmentary remains and are in scattered collections, but several of them are based on practically complete skeletons. With two exceptions all of these skeletons are deposited or exhibited in museums outside of Indiana, which has no state museum of its own.

The portion of Indiana where mastodons are found most abundantly is in the north and east. Perhaps the finest skeleton known was found in DeKalb County and is on exhibit in the Carnegie Museum in Pittsburgh. Another excellent completely mounted specimen was found in Pulaski County and is now on exhibit in the United States National

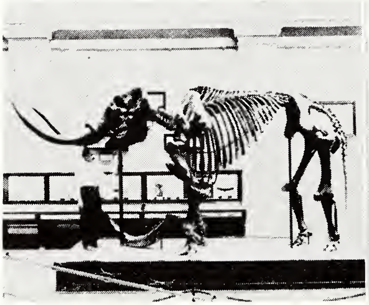

Fig. 1. Pulaski County; United States National Museum.

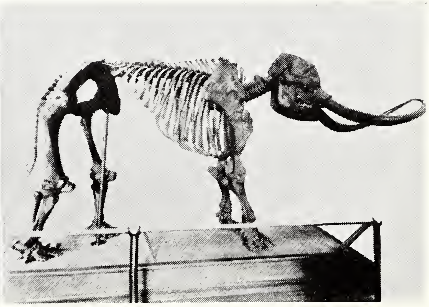

Fig. 2. Miami County; Milwaukee Public Museum.

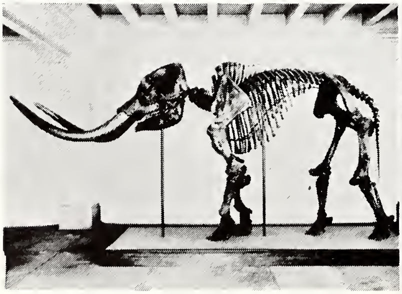

Fig. 3. DeKalb County; Colorado Museum of Natural History.

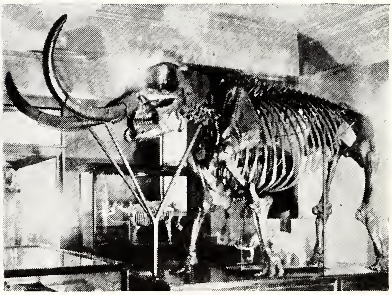

Fig. 4. DeKalb County; Carnegie Museum, Pittsburgh.

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* Read in the general session of the Academy.

Museum. One of the early mastodon skeletons found in Indiana came from the vicinity of Denver, Miami County, and is exhibited in the Public Museum of Milwaukee. The last good specimen of mastodon was found near Garrett, DeKalb County, and is exhibited in the Colorado Museum of Natural History. A fairly complete skeleton from Marshall County, as yet unmounted, is in the collection of the American Museum of Natural History. Another fairly complete specimen, as yet unmounted, from Noble County is in the Buffalo Museum of Science, New York.

Two good unmounted specimens are in Indiana collections, an immature one at Taylor University from Grant County, and another at Earlham College from Wayne County. The Earlham specimen, which was dismounted at the time of their fire, is now being reassembled.

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